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MISSION TO PLANET EARTH

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

ON

THE MISSION TO PLANET EARTH

MARCH 8, 1989

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MISSION TO PLANET EARTH

WEDNESDAY, MARCH 8, 1989

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met at 9:32 a.m., in Room SR-253, Russell Senate Office Building, Hon. Ernest F. Hollings [Chairman of the Committee] presiding.

Staff members assigned to this hearing: Marty Kress, Penny Dalton, professional staff members; and Sherman Joyce, minority staff counsel.

OPENING STATEMENT BY THE CHAIRMAN

The CHAIRMAN. The Committee will come to order.

We have had some travel overnight to get here with Dr. Ride and others, and we are very much indebted to them.

I could read my statement, but I think my staff is trying to outdo our distinguished friend from Tennessee. Listen to this: For nearly 20 years, since the first American left his footprints in the dust of the moon. I have got to stop right there.

I will read it later but first I would simply observe that we have many reports now that pertain to the planet Earth. We have "The Changing Planet: The U.S. Strategy for Global Research;" we have the report of the Space Science Board: "Space Science in the 21st Century—Mission to Planet Earth;" and we have a special *National Geographic:* "Can Man Save this Fragile Earth?," and a special *Time Magazine,* "The Endangered Earth."

But it really was not until Dr. Ride made her report to the Administrator of NASA, "Leadership: America's Future in Space," that the concept gelled and got everyone's attention. I think, Dr. Ride, it was your report that got our attention. I was thinking this morning about a poem I learned back at school by Robert Burns. Was it not—I do not want to say Ode to a Louse, but that was what it was called: Would that God the gift to give us, to see our ourselves as others see us.

So if we can use our space assets and look back down on a mission to Earth, look and study our own planet in a comprehensive fashion we will really have accomplished something, in my opinion. We are grateful to each of the three of you.

For nearly twenty years, since the first American left his footprints in the dust of the moon, this Nation has been in search of major goals for its civil space program. Many goals have been proposed, but none has succeeded in capturing the imagination of the

American people and the world community as much as the Mission to Planet Earth.

Maybe that's because of the renewed worldwide interest in global change and our fragile planet Earth, or maybe it's because of our basic desire to know more about ourselves and the planet we inhabit. Be it the timing, the proposed goals and objectives of the Mission, or its basic appeal, the concept of a Mission to Planet Earth has been recognized as a goal worthy of pursuit and as a priority within the civil space program's agenda. The concept of the Mission to Planet Earth has been endorsed by a broad range of scientific organizations and advisory groups with domestic and international composition, and it was endorsed by President Bush and Governor Dukakis during the 1988 presidential campaign.

The Mission to Planet Earth is the most challenging and exciting concept that this Committee has seen in quite some time, and we look forward today to hearing from our distinguished witnesses on how to translate that concept into a program for the next decade. In light of growing world interest in global change issues, a comprehensive international study aimed at understanding our planet and the changes which are taking place on it is the right type of mission to be discussing.

I am pleased that Dr. Salley K. Ride of Stanford University, Dr. Don Anderson of the California Institute of Technology, and Dr. Lennard Fisk, Associate Administrator of NASA, are able to testify at this hearing.

Each of these witnesses offers a unique perspective to this mission, and everybody will benefit from their expert testimony.

Dr. Ride's report, "Leadership and America's Future in Space" gave birth to the concept of the Mission to Planet Earth and identified this mission as a priority within the civil space program's agenda. As one who has been there and a physicist, Dr. Ride can talk authoritatively about the role of space-based systems in improving our understanding of planet Earth.

Dr. Anderson's report on the Mission to Planet Earth was part of the National Academy of Sciences' report on "Space Science in the Twenty-First Century" and lays out a comprehensive research strategy for carrying out the Mission to Planet Earth. Dr. Anderson brings the unique view of the university research community to this discussion, as well as his interesting perspective on the earth-based systems and data management requirements of this Mission.

Finally, Dr. Fisk will describe the activities that are under way and being planned by the involved federal agencies (NASA, NOAA, NSF, DOD, etc.), the interested foreign governments, and the International Space Year Association to define, organize, and implement the proposed Mission to Planet Earth. Dr. Fisk has the enviable task of making this dream a reality.

I am most pleased that each of you could join us today. Protecting fragile planet Earth has become a rallying cry for men of all Nations, and Mission to Planet Earth offers the United States a unique opportunity to reclaim its leadership status in space and at the same time to put its scientific and technological expertise to use for the benefit of all mankind.

Thank you.

Let me yield to my colleague, the chairman of our Subcommittee. Senator Gore?

OPENING STATEMENT BY SENATOR GORE

Senator GORE. You started off disclaiming any eloquence or effort there toward, and ended up quoting Robert Burns. I do not know what to make of it.

I was reminded when you showed this "Time" magazine issue, Planet of the Year, that Jay Leno on the Tonight Show said this was really unfair because all the judges were from the same planet.

Anyway, I will ask consent to put my opening statement in the record, too, Mr. Chairman, but let me just make a very few opening comments.

About a month ago there was a prominent story on the front page of the "New York Times" about a scientist who had compiled NOAA's temperature records in the continental United States and had come to the conclusion that in the continental U.S. there had been on global warming over the past 100 years.

From time to time we are presented with little snippets of data that seem on a surface analysis to undercut the growing consensus among scientists all over the world that we are in the process of a global ecological crisis representing a profoundly new relationship between the human species and the planet Earth.

Last fall I traveled to East Anglia, near London, and talked with a group of scientists who had compiled a global temperature record, taking the temperature readings from sea captains in the middle of the Atlantic and Pacific over 100 years or so, separating out the recordings made at weather stations near airports with concrete and local pollution affecting the measurements.

And that global temperature record shows very clearly what the temperature record in the lower 48 States did not. The difference between the two records is to be found in the realization that the continental United States, even though it seems to many of us, as most of the world, represents 1.5 percent of the Earth's surface.

So the kind of perspective which science and humanity can gain from the sort of program that Dr. Ride and her colleagues have put forward is really the only perspective which can give us the insights and knowledge that we need to deal with this crisis.

I remember about 15 years ago seeing a startling picture that grabbed my attention for some reason. It was a computer-generated picture of Abraham Lincoln. It had large rectangular blocks of differing lightness and darkness. And if you look at it up close it looks like a jumble of blocks. But if you step back about 15 or 20 feet there is Abraham Lincoln's image just as clear and sharp as anything you have ever seen.

Well, the temperature record of 1.5 percent of the Earth's surface is akin to one of those blocks in that picture, that mosaic picture of Abraham Lincoln. And if we try to understand this process of change we are living through by looking from a terrestrial point of view up close at regional changes or local changes, we will not see the pattern which is so clearly apparent from a global point of view.

How do we get that global perspective? Space. It is the easiest, cheapest, most efficient, best way to put together all of the data that we need at the time we need it. You know, the Chairman has worked extremely hard for a period of years to save Landsat, and his efforts, I hope, are bearing fruit this week, although it is like the Perils of Pauline, is it not, Mr. Chairman?

The CHAIRMAN. Yes, it is.

Senator GORE. The tentative decision to cut out Landsat just at the time when we need that continuing record strikes me as one of the dumbest decisions I have ever seen. We need to go beyond the point of just keeping Landsat in operation, which is a bare bones minimum of what any reasonable person would do, and expand upon that sort of data-gathering and analysis.

Dr. Ride, we are indebted to you and your colleagues for really digging in to analyze exactly how we can go about that in a very sensible, cost-effective way. As Chairman of the Space Subcommittee, working with the Chairman of the full Committee and all of our colleagues here, I want you to know that it is my own personal top priority for NASA's agenda.

Having just returned from the conference in London this weekend where 120 nations were examining the ongoing damage to the ozone layer, I can tell you that there certainly seems to be a lot of evidence that all over the world men and women are quickly changing their attitude about what we have to do and how we can go about doing it.

I am fond of citing the old science experiment where the frog is dropped into a boiling pot of water and jumps out, but if you put the frog in first and slowly boil the water the frog will just sit there and get boiled because its little nervous system does not make the connection between the signals of danger and what the proper response ought to be.

Our environment is reaching the boiling point. Our relationship to the planet has changed dramatically in our lifetimes. We need the sort of program we are looking at here today to tell us how to do it and how to do it quickly. So I am looking forward to it.

More than 120 nations, as different as China and Costa Rica, as different as the United States and India, gathered this week in London because of one very important similarity: concern for the global environment we share.

The United States was represented at that conference. I was proud to be a part of that delegation. The issues that dominated our international discussions—the chemicals tearing at the earth's protective ozone shield, the consequences of their continued use and emission—cast a shadow here at home, at these hearings today.

We know there'a a problem. We know we must act—to control ozone-eating chemicals, and to control other chemicals and gases that are threatening our environment and our future. But for too many politicians and policy makers—of every party in nearly every country—the evidence isn't overwhelming enough. Uncertainty becomes an excuse for inaction.

Mission to Planet Earth can help provide the evidence to shift reluctant politicians and policy makers into gear. Information is critical to steer our policy decisions—information from both space-

based and earth-based systems, intergrated by innovative means to expand our view of the world and how it might change—due to our own actions and, because of nature's.

As you know, I have long been deeply committed to the issue of global environmental change. Already in this committee, we have held important hearings on global warming and ozone depletion.

There is a broad-based consensus on the need for a comprehensive global change research program to provide information critical to formulating the policies that will protect our fragile planet. We know enough now to take action: for example, we should ban the production of chlorofluorcarbons within five years to protect the stratospheric ozone shield. We must reduce CO2 emissions, stop deforestation, and take numerous other remedial steps. Mission to Planet Earth will build upon that knowledge so that we can continue to develop policies that meet the global environmental challenge we face.

Activities are underway in the federal government to formulate a Global Change Research Program, in the science/research community to initiate the International Geosphere-Biosphere Program, and in the U.S. International Space Year Association to make the Mission to Planet Earth one of the key agenda items for 1992.

As organizers begin preparing for the 20th Anniversary of Earth Day on April 22, 1990, and for the 20th Anniversary for the day man first stepped on the moon, July 20, 1989, I can think of nothing more appropriate than using our space science technology to address our environmental concerns.

In January, 1989, *Time* magaine named the "Endangered Earth" the Planet of the Year. It is my hope, that our country, working with other nations of the world, will announce its resolve to protect our endangered planet and improve its environment by the beginning of the 21st Century. Mission to Planet Earth can help us reach this critical goal.

Mission to Planet Earth is also clearly a major component of the nation's space program, taking its place alongside other key priorities.

For the past five years, an extensive debate has been going on in Washington, DC, concerning the future scope, breadth, and dimension of the nation's civil space program. This debate was inaugurated by Congress in 1984 when it instructed the President to establish a National Commission on Space, the Paine Commission, to "identify long range goals, opportunities and policy options for United States civilian space activity for the next 20 years."

But when the Paine Commission's excellent report was submitted to the White House in mid-1986, America was looking back, not ahead. The release of this report was overshadowed by a single, tragic event that occurred earlier in the year—the Challenger accident. The nation's attention was focused solely on the findings of the Rogers Commission, which has been assembled to investigate the catastrophe. The Paine Report went almost unnoticed.

Fortunately, the quest to establish a long range space policy continued. In 1987, under the leadership of Dr. Sally Ride, NASA initiated a study of four potential space initiatives in an effort to energize a discussion of the long-range goals. Simply put, the Ride Report tried to answer two basic questions: Where do we want to

be at the turn of the century? and, What do we have to do now to get there? In formulating these answers, the report also tried to balance the visions of the Paine Commission Report with the realities of the Rogers Commission Report.

Did the Ride Report succeed? It succeeded where past reports failed; it succeeded in capturing the imagination of the American public and the presidency. It not only energized a debate; it helped focus that debate on a clear set of potential goals in space, including what is now known as the Mission to Planet Earth.

Mr. Chairman, I'd like to compliment you and the Ranking Member of the Commission for bringing together our distinguished group of witnesses to discuss this important and timely topic.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you.

Senator Burns?

OPENING STATEMENT BY SENATOR BURNS

Senator BURNS. Thank you, Mr. Chairman.

I would echo those concerns while we go into this important subject. The history of the Earth has always been one of change. As far back as we can study this Earth has been in constant change.

For many, many years we went through a time when that change was unnoticed because we did not have the tools to really recognize that change. Now that we do and we have the technologies, we probably have a better understanding now of this change and how constant it really is as more people inhabit this little piece of mud that is whirling through space. And now we know better the effects of the change.

It would be remiss of us to ever stop or cease the continuing technologies and tools to monitor that change. It would be even more remiss of this society to not start taking the knowledge that we are gathering from those new technologies and tools, all that information and now start applying it to our everyday observation of the Earth and its environment.

So I think this is a very important mission for us. It is an important mission for this society to undertake. That is all I have to say at this time on this very, very important subject.

The CHAIRMAN. Thank you. Senator Exon?

OPENING STATEMENT BY SENATOR EXON

Senator EXON. Mr. Chairman, thank you very much.

Let me go beyond the usual statement and say I salute you for your dedication and that of the Chairman of the Subcommittee on calling this hearing. It could not come at a better time.

When we look forward to what we are going to do on this planet that we are going to leave to those who follow, I think that there is no more important responsibility that this Committee has in this session of the Congress than to move ahead with dispatch on what Dr. Ride and her associates have recommended to us. It is not necessary that we follow exactly what they have lined up, but I congratulate you, Dr. Ride, for the significant contributions you have made.

It just seems to me that we have got to get our priorities lined up. Gramm-Rudman-Hollings and all of the other restraints that we have on the budget notwithstanding, there is no more potential danger to this planet than the one that we are addressing here today.

Senator Burns and I and others come from the great midsection of America, where we do not have the massive population and therefore it has been easier for us to be a little more sensitive to the environment. But we have recognized that the environment and what we do and do not do with it is critically important.

Moneywise, it has been estimated that to carry out basically the program that has been suggested would be a cost of between $22 billion to $30 billion over the next 10 to 15 years. When you measure that with the more mundane but even less important priorities—I would cite the money that we are going to have to spend, between $100 billion and $200 billion, in the next 10 years to bail out the savings and loan industry; we are going to have to spend somewhere between $150 billion and $250 billion to clean up the nuclear waste at just our military installations—then it seems to me that as expensive as it is, the estimated $22 billion to $30 billion over the next 10 years to save the planet for future mankind has to be one of our highest priorities.

Thank you for calling the meeting. I think it is time we move ahead aggressively.

The CHAIRMAN. Thank you. Senator Kerry?

OPENING STATEMENT BY SENATOR KERRY

Senator KERRY. Thank you very much, Mr. Chairman.

We are all anxious to hear the panelists testify. But I would like to say that, thanks to you, Mr. Chairman, last year I was able to chair a hearing in Boston under the Subcommittee at which Dr. Fisk testified, and Dr. Mary Cleve testified, and in fact we discussed at that time many of the space science applications and much of what can be done and has been done already from space.

I think that perhaps one of the most extraordinary things about Mission to Planet Earth is that it has not been something on the agenda, fully-funded and adequately undertaken, prior to this. I think the testimony today will underscore the degree to which we know so little about our planet and the degree to which we need stronger models by which to measure and make judgments about where we are going.

So I want to thank you, Mr. Chairman, for continuing this process of educating us as well as the country. I only hope that we are going to make some of the fiscal choices necessary to enable us to move on this agenda, which is becoming so much more compelling than I think most people can even comprehend because of the depth of some of the problems we face.

So I thank Dr. Ride for her efforts and leadership, and Dr. Fisk and others, and I look forward to proceeding. I would ask the indulgence of the Committee and the panelists. I have to chair a narcotics and terrorism subcommittee in ten minutes, so I cannot remain for this, but I will read the record with great interest. I thank you.

The CHAIRMAN. We thank you, Senator Kerry.

Senator Rockefeller?

Senator ROCKEFELLER. No statement.

The CHAIRMAN. Senator McCain?

Senator MCCAIN. No statement, Mr. Chairman.

Senator DANFORTH. No statement, Mr. Chairman.

The CHAIRMAN. I have statements from Senators Pressler and Kasten that I will include in the record.

[The statements follows:]

OPENING STATEMENT BY SENATOR PRESSLER

Mr. Chairman, I am pleased to be an original cosponsor of the National Global Change Research Act. We need to understand the global changes which are occurring and which in many cases we are causing. We need to understand them, because until we understand them, we will not know how to cope with them. We will not know what we need to do to minimize them.

As you know, Mr. Chairman, I was also an original cosponsor of the National Science and Technology Policy Amendments, which you introduced last year. I am committed to doing what I can to enable us, as a nation, to address this problem. This legislation does a great deal of good in establishing an overall framework for interagency cooperation in global change research.

I am interested in this problem for a number of reasons. As are most Americans, I am concerned about the ultimate effect of the increasing rate of ozone depletion in our atmosphere. I am concerned about the greenhouse effect. Do we really know how fast the global mean temperature is rising and what can be done about it? What about changes in weather patterns? Will we see yearly droughts in this country's breadbasket? Or was last year's hot weather a normal aberration?

The government is beginning to focus on this problem. But we need to coordinate and promote both current and planned efforts by our various agencies. We have the research capability. We have the skilled manpower. We just need to do it.

Another reason I'm interested in this subject is because I know firsthand of the quality work done at the Earth Resources Observation System (EROS) Data center in my home State of South Dakota. This center has been archiving and distributing land remote sensing data since 1973. It is now the home of the National Satellite Land Remote Sensing Data Archive, which will be transferred from the National Oceanic and Atmospheric Administration to the Geological Survey in Fiscal Year 1990. It will also be used by NASA for processing, distributing, and archiving land remote sensing data acquired by the Earth Observing System (EOS) component of the Space Station Polar Platform, which is projected to be operational by the mid-1990s.

This Center, as well as the many other resources of the federal government, can be put to good use in a coordinated manner to explore global change. That is what this bill would do. But as we plan for the future, we must not forget past and present efforts. Past knowledge of the condition of our environment must be preserved as a valuable data base for long-term comparisons and decisions. Facilities such as the Land Remote Sensing Data Archive provide extremely valuable historical data.

Which brings me to a final point. Landsats 4 and 5 continue to operate, providing important information for global change research. Yet current funding for the Landsat program will cease on March 31. If we are really serious about global change research, we must keep these satellites functioning and providing information.

Mr. Chairman, thank you again for holding this hearing. This is one of the most important issues confronting the world today.

OPENING STATEMENT BY SENATOR KASTEN

Mr. Chairman, I look forward to hearing from today's panel of witnesses on the "Mission to Planet Earth" initiative. This proposal, one of four advanced by the task force chaired by Dr. Ride to determine the long-term direction of the civilian space program, should receive great attention in light of this country's, and the world's, increased concerns about our environment here on earth.

We have recently held hearings on the problems of global warming and ozone depletion in which the work of NASA on its own, and as a coordinator of other programs, has been in the forefront.

We are proud of the many scientific advances that have developed out of our space program to assist us in addressing society's problems. This program would specifically direct the knowledge and information gathering capabilities of our space program to better understanding the forces shaping our global environment. These problems I believe are some of the major public policy questions that we, and the other governments of the world, must face in the near future.

As so many of our environmental problems are global in nature, I am pleased that this initiative involves international cooperation. Because this program hinges on the existence of the Space Station, and its funding is before this committee now, decisions must be made. This hearing will be educational, and I look forward to learning more of the budgetary impact as we proceed.

I welcome our witnesses, and thank you Mr. Chairman.

The CHAIRMAN. The witnesses have agreed as a favor to us to appear as a panel since each of them are authorities in their own right. We have this morning an opportunity to listen to them all at once and then we will ask our questions after their presentations.

The Committee is delighted to have Dr. Sally K. Ride of Stanford, Dr. Donald L. Anderson of Cal Tech, and Dr. Lennard A. Fisk of NASA.

Dr. Ride, you may proceed, please.

STATEMENT OF DR. SALLY K. RIDE, STANFORD UNIVERSITY CENTER FOR SECURITY AND ARMS CONTROL

Dr. RIDE. Thank you very much, Mr. Chairman and members of the Committee. I appreciate the invitation to participate in this hearing. I think it is an important one. I have prepared a statement that I would like to read for the record.

In 1987, as you have mentioned, I directed a NASA internal study on possible initiatives for the U.S. civilian space program. Mission to Planet Earth was one of those initiatives and I am very pleased to have the opportunity to discuss some of the main points of it today because I believe it is an important initiative.

This Committee has recognized and has documented the importance of global change. You have devoted several hearings both to the broad topic and to some of the specific issues. Mission to Planet Earth is an initiative that would help us to gather and to analyze the data that I believe is required to understand the forces that are behind global change and to understand some of the possible implications for our planet and for ourselves.

I might say that the members of the Committee have already perhaps summarized my statement as well as I will be able to. I think that the points that you have made are excellent points.

The key point that I would like to make at this hearing, that I think Senator Gore made very well, is that the study of global change requires a global perspective and it requires global observations. Our space program enables us to make those observations. Without the perspective that we can gain from space, we just cannot adequately monitor, much less characterize, the dynamic changes that are going on and the dynamic forces of the planet.

Space exploration, as you know, has revolutionized our perception of the planet that we live on. In the 1960s, the Apollo program provided us with a new perspective of the planet and I think the pictures that we got from the lunar surface looking back at Earth really drove home to all of us on the planet what a fragile place

Earth is and helped to crystallize the environmental movement in the late 1960s.

The space program has continued to contribute over the last couple of decades to our understanding of our home planet, and I am sure we will be discussing many examples of that this morning. But our understanding is very far from complete. The Earth is a very complicated place, as we are beginning to understand better and better.

Over the last couple of decades scientists have come to realize that the Earth is very definitely a synergistic system and that it has to be studied as a system. As the Committee has heard over several of its hearings, I think, the oceans, the atmosphere, the continents, the biosphere, are all highly interactive and you cannot understand any one in isolation; you need to study them as a system. Furthermore, it has become clear that changes in any one of the components can and do reverberate through the entire system and have influences on a very global scale.

Scientists have also come to appreciate that our activities have begun to affect the conditions on the planet. Whether we like it or not, we are very active and very influential component of the Earth system, and if we are going to avoid being a destructive force on the planet and adversely affecting conditions on the planet we have to be sure that we understand the consequences of our actions.

Right now we do not understand how our planet works. Current models of the Earth system just are not good enough. We need better, more comprehensive, observations and in particular we need observations from space to complete our understandings.

Now I would like to say that ground-based measurements are essential and I am going to underscore that point again later. But they provide only small pieces of what is a much larger puzzle, and to unravel what is actually a frustratingly complex tangle of interacting physical, chemical and biological processes we just have to mount a concerted effort to study them from space.

Now you have heard about the importance of researching and understanding global change. The concept behind Mission to Planet Earth is to take advantage of the capabilities of our space program, and those are significant capabilities, to develop an integrated approach to studying the Earth. What I mean by that is establishing a global observation system in space.

Now, what would a system like this look like? It would include a suite of experiments, a suite of sensors in polar orbit, in low inclination orbit, and in geosynchronous orbit, and it would also include a data system that would integrate the information from space and also from ground-based measurements. Experiments would measure things like global cloud cover, vegetation cover, ice cover, global rainfall, ocean chlorophyll, ocean levels, tectonic plates, atmospheric concentrations of ozone and of carbon dioxide. I think it is clear that a program like this would contribute significantly to our understanding of global change.

What do you need in space to gather this sort of information? We concluded that to meet the objectives of a scientifically comprehensive global observing system Mission to Planet Earth would include four sun-synchronous, polar-orbiting platforms; five geosynchro-

nous satellites—that is the number that is required to cover the whole Earth; experiments in satellites that are carried to orbit by both the space shuttle and/or expendable rockets; and experiments that are attached to the space station. We can get into the details of those later, if you like.

Also let me say again that a crucial element of the system would be a data-handling and data-processing system that would make this information that we gather available to scientists all over the world.

Now, I believe that the United States should be a leader in Mission to Planet Earth, but it is important to point out that it is inherently an international problem and it has to be an international effort. There are several other nations that have supported this and related concepts and in particular I would point out that Mission to Planet Earth has been endorsed as a primary focus for the International Space Year in 1992.

I would like to see the United States lead Mission to Planet Earth with all members of the international community being encouraged to contribute either ground-based or space-based experiments, depending on their capabilities and interests. Just as an example, it has been suggested that two of the polar platforms and two of the geosynchronous platforms might be contributed by other nations or groups of nations.

NASA certainly has the technical and the scientific expertise and particularly the experience in directing and conducting observations of the Earth from space to be able to lead a Mission to Planet Earth. But again it should be emphasized that you cannot understand global change from space-based measurements alone; ground-based experiments are a critical component, a very important part of this research.

What that means is that the initiative requires the involvement, coordination and cooperation of several U.S. Government agencies, not NASA alone. I think a high priority should be given to defining and assigning the roles and responsibilities of the various U.S. Government agencies.

Let me just summarize by emphasizing again that it is only from Earth orbit that we can get the appropriate perspective to perform this global study. We know what to observe. We now know how to observe it. We have the capabilities to observe it. And while it may be overly dramatic to say that the survival of the planet depends on an understanding of global change, it is not overly dramatic to say that there are important questions that will be facing us in the coming decades and that the scientific return from a Mission to Planet Earth could significantly enhance the quality of life on this planet.

Our space program in this case, I believe, is a national asset. As we have developed the capability to explore other worlds, we have also acquired the ability to explore our own world in ways that would have been impossible only a couple of decades ago.

It is important to recognize the very key role of space in understanding Earth and to exploit our space program not only to explore other worlds but to explore our own world as well.

Thank you.

The CHAIRMAN. Thank you. Dr. Anderson?

STATEMENT OF DR. DON L. ANDERSON, SEISMOLOGICAL LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY

Dr. ANDERSON. Good morning. My name is Don Anderson. I am Professor of Geophysics at Caltech, and I was Chairman of the task group on Earth sciences which prepared the National Academy report "Mission to Planet Earth" which you have already heard a little bit about.

This was an activity of the National Research Council of the National Academy of Sciences. Early in 1984 NASA asked the Space Science Board to undertake a study to determine the principal directions and principal issues that the discipline of space science would face in approximately the years from 1995 to 2015. We had a two-year study and a final report was issued by the Academy early last year.

My particular task group was composed of oceanographers, meteorologists, geophysicists, chemists, and space physicists, and they represented about ten different institutions, including universities and government laboratories. In spite of the fact that this is a very broad spectrum of Earth scientists, they agreed on the importance of a Mission to Planet Earth and, not only that, they agreed on the strategy of the Mission to Planet Earth.

In fact, the frontispiece of our report, which is our consensus, states: "We now have the technology and the incentive to move boldly forward on a Mission to Planet Earth. We call on the nation to implement an integrated global program using both space-borne and Earth-based instrumentation for fundamental research on the origin, evolution and nature of our planet, its place in our solar system, and its interaction with living things, including mankind."

Now this is a very broad statement and it is much broader than we have heard so far. It involves a lot more than the climate. It is a lot more than the environment, and it is a lot more than global change. It is basically a call to mount a basic research mission similar to those we have mounted for other planets and to try to understand the Earth, from the innermost solid core to the outermost reaches of the atmosphere. So it is a lot more than just addressing the current concerns. It is anticipating future concerns.

The report outlines a unified program for studying the whole Earth, from its deepest interior to its fluid envelopes, and it proposes a system of measuring devices including Earth-based and space-based. We split the program up into four identifiable scientific objectives which we called grand themes.

These include: to determine the origin, composition, structure, dynamics and evolution of the Earth's crust all the way from the surface and the atmosphere to the deep interior so that we understand where our planet came from and where it might be going;

Secondly, to establish and understand the structure, dynamics and chemistry of the oceans, atmosphere and cryosphere and their interactions with the solid Earth;

Thirdly, to characterize the history and dynamics of living organisms on the Earth and their interaction with the environment;

And, lastly, to monitor and understand the interactions of human activities with the natural environment.

A focus on all of these themes will help us to understand the origin and fate of our planet and to place it in the context of the solar system.

As the population of our planet increases and as our activities extend into places such as rain forests and earthquake-prone regions and even volcanic regions, as we remove material from the Earth and inject it into the atmosphere and into our groundwater systems, it becomes more and more important to understand our planet and what we are doing to it.

It seems that every year there is something new that we focus our attention on, whether it be the eruption of Mt. St. Helens or a large earthquake in southern California or Armenia. The El Nino one year grabs our attention and then it is the ozone hole and then it is global warming and droughts.

We really do not know very much about Earth. We have not been able to anticipate these events basically because we have never had a global program to really understand our planet. So the idea of Mission to Planet Earth is to finally focus our resources on our own planet, apply the technology that we have developed in outer space and in exploring the other planets to understanding our Earth. We should not approach each little problem in its own right but put it in the context of understanding the whole Earth.

Let me repeat that there has never been a systematic study of our own planet. Part of this is because there are international jurisdictional problems and, more importantly, there are interagency problems in this country. There is no single agency that is responsible for the whole Earth; certain agencies pick off a piece of it. I do not know if we can do anything here today to help correct that, but in order to study the whole Earth, as a planet, we are going to have to address these jurisdictional problems.

We have been able to go to other planets and study them systematically. The Viking mission to Mars, I think you all remember, was one such mission and there was no particular jurisdictional problem there. There was one agency involved and one country involved. We sent up several orbiters and several landers and we were able to design a systematic program with a small number of instruments, to address most of the pressing scientific problems of that planet.

If you were to try the same thing on the Earth I think you understand that it would have to be an international program and would have to be an interagency program. It would have to involve things sitting on the ground. It would have to involve things orbiting in space.

In fact, it is much more complicated to study the Earth than it is to study the other planets in the solar system because we have an ocean. We live on a very complex planet. We occupy the largest terrestrial planet and we have plate tectonics. As far as we know, Earth is the only planet that has life and plate tectonics and an ocean. So we have to have orbiters, we have to have landers, we have to have things floating around in the ocean and we have to have things on the ocean bottom.

But we know how to do all of these things. It is just a matter of having the national and the international will to mount this particular mission.

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We also learned that you cannot isolate the subsystems of the Earth, such as the atmosphere or the oceans and the crust, from each other. The Earth is a very complex interactive system. In fact, life itself and mankind itself interacts with the other parts of the Earth.

Recently you have heard a lot about global change programs and things that relate the interactions of the surface of the ground and mankind with oceans and atmosphere, but Mission to Planet Earth takes an even broader view. For example, volcanic processes and processes that happen underneath the ocean inject gas and warmth and energy into the system. We cannot even understand the Earth ocean system without understanding the deep interior.

There is also useful information associated with the magnetic field and radiation belt which are basically caused by convection in the deepest part of the Earth. The fluid outer core is convecting and that is why we have a magnetic field. It is a good thing we do because we are shielded from harmful radiation by the magnetic field.

In short, the message I want to make primarily is that in order to understand the Earth you have to study the whole Earth. You cannot bite off a piece of it and think that you are learning about the whole system.

The proposed Mission to Planet Earth is an ambitious collection of automated orbiters and intelligent land and ocean observatories and they are collecting data from all parts of the globe and transmitting in real time to central data collection agencies and then to scientists. It is the kind of program that the scientists are deeply involved in from the beginning and they are studying the operation of the Earth system in almost real time.

During the past five years there has been a large amount of planning for a study of the Earth as a global system and for observing systems to monitor global change. The Mission to Planet Earth is the first of these missions to propose an integrated study of the whole planet rather than just the atmosphere, the ocean or some small part of it.

To observe such an interactive and complex system as Earth we need both satellite and surface measurements. Satellites provide the global context and most often are the only way to acquire global data. Geostationary satellites provide rapid images of the whole Earth. Polar orbiters provide high-resolution data and fill in the polar gaps. Special purpose orbiters at various inclinations and altitudes provide measurements as needed and communicate with instrumentation on the surface and in the atmosphere.

Our recommendation is a set of five geostationary satellites (two provided by the United States), two to six polar-orbiting platforms (two to three provided by the United States), a series of special missions that require other orbits, a system of complementary Earth-based observing systems, including land and ocean-based observatories transmitting their data in real time, a coordinated system for achieving and disseminating Earth-related data and theoretical research and computer modelling. The theoretical and ground based studies can start immediately. The space-based components will need a ramp up time.

Mission to Planet Earth cannot and should not be done by the United States alone. Fortunately, there is a long history of collaboration by Earth scientists of all nations. Geologists work in all countries of the world. Oceanographic expeditions are multinational. There are global seismic networks which share their data freely. There are joint space missions. There are several new international projects including global change and lithospheric studies.

The United States must view its own program as one contribution to an overall international program—both to obtain access to scientific and technical communities and to develop the global system of in-situ observations.

The task group recommends that steps needed to assure the required level of international participation and cooperation be taken at the early stages of program planning.

It may be easier to involve many nations in this common program than to work out the interagency problems in this country.

This is obviously a high-technology mission and NASA will play an important role. The proposed mission is a comprehensive program that deals with all of the most exciting and important questions in Earth sciences today. NASA has outstanding programs in atomospheric and oceanographic sciences and needs to become stronger in solid Earth sciences, the sciences of the surface and the interior of the planet. It is clear that other agencies must also be involved but there is at present no agency that has an unmistakable mandate for whole Earth problems. If NASA is to be a lead agency it must be allowed to develop and operate ground based stations, or, as they are sometimes called, zero-elevation orbiters.

NASA should continue to play the key role in the development of space-based technology and the complementary earth-based systems, together with the necessary data systems, as new observatories for the Earth are developed. While NASA has developed a comprehensive program in the planetary sciences, such plans have never included the Earth, in spite of the fact that it is impossible to design a program of real value for Earth science, including solid Earth science, that does not include high technology systems and space based systems.

Study the Earth introduces problems which do not exist in the study of other planets. There are many agencies working on parts of the Earth problem but there is no integrated program and hence we are ignorant of many of Earth's secrets. Some basic questions are not being addressed by any agency.

Communication among OSTP, OMB and the agencies involved in civilian Earth science research is needed to develop coordinated programs and budgets. This requires full cooperation between NASA, NSF, NOAA, USGS, DOE and others. The absence of a well-coordinated organizational structure at the federal level for conducting global Earth science must be addressed. The distinction between "research", "operations" and "monitoring" is sometimes artificially forced. Mission to Planet Earth is a basic research mission but it clearly involves what is often called "operations" and "monitoring" tasks, tasks which, in many cases, are best carried out by NASA or other research agencies.

In conclusion, I would just like to say that we now have the technology and the incentive to mount a Mission to Planet Earth and I

would like to recommend that the United States implement and integrate a program of fundamental research on the origin, evolution and nature of our planet and its place in the solar system and its interaction with mankind. I will stress again that it is a basic research mission.

We also need specialized missions to address certain problems, such as ozone holes and global warming, but we also need a more general and more research-based program so that we do not overlook a very important part of the system. For example, the drought last year was quite a surprise, and there have been many theories put forth as to why there was a drought. Some of these include oceanic circulation, temperature of the ocean, the absence or presence of El Nino.

One of the most interesting suggestions is that we had a drought because there have not been any large low latitude volcanos in the last five years, which inject aerosols into the atmosphere and help control the climate. This is just an example of where by ignoring part of the system we might be ignoring the secret to the system.

The National Academy of Sciences endorses the Mission to Planet Earth. The American Geophysical Union, of which I am president for two years, has adopted a Planet Earth initiative which states in part that the U.S. should take the initiative amongst nations to establish an international observing system which, in conjunction with an active research program, will allow scientists to understand natural and anthropogenic changes in the Earth's environment and the global scale forces that control them.

I would just like to wrap up by suggesting that Mission to Planet Earth is a worthy candidate for inclusion in this nation's high priority scientific options. Thank you.

The CHAIRMAN. Thank you a lot.

Dr. Fisk?

STATEMENT OF DR. LENNARD A. FISK, ASSOCIATE ADMINISTRATOR FOR SPACE SCIENCE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Dr. FISK. Thank you very much. I also have a prepared statement that I would just like to include in the record, and I will highlight a few points. If you will indulge me, as sort of the consummate NASA official, to use a few viewgraphs here—can I be heard without using the microphone?

The CHAIRMAN. Let us try it.

Senator GORE. You can just pick up the microphone and carry it with you.

Dr. FISK. I have a classroom voice, too, if that is necessary.

You have heard from several speakers—Senator Gore summarized it, I think, very well—that there is a lot of concern over the future of our environment. We have global warming. We have acid rain. We have deforestation issues and so on. And they are global issues which require the global perspective of space in order to be able to accumulate the data necessary to give you the scientific understanding which is in turn the basis of sound policy decisions.

[Slides shown.]

Dr. FISK. Mission to Planet Earth is a concept that has been put forth, which includes the following elements that Sally mentioned. We have the polar platforms. These are the polar platforms of space station and on the polar platforms of space station could be flown a set of instruments which is known as the Earth Observing System, or EOS. I am going to concentrate on that one in particular.

It includes attached payloads on the manned space station and includes something called Earth probes, which is essentially focused on relatively small missions which require in many cases different orbits than you can get with a polar platform going over the poles or with a manned station in equatorial orbit. And finally there is the concept of geostationary platforms. Again, these would sit over one particular region of the Earth and make concentrated studies.

That in turn all feeds into a global data set which in turn gives you interactive models. You have processes studies, including a great many ground-based research activities and what you are really after is assessment and prediction.

Now let me tell you where we are in the process of planning for Mission to Planet Earth.

Now there are a lot of things on here but my intent is to simply use this as a device to try and highlight where we are in this process. You can go back and start in many places here, but in 1982 the Academy released its first report on a Strategy for Earth Science from Space, and all of the NASA missions which deal with science have their origins in an Academy study, as in particular the Academy study that we have just mentioned by Dr. Anderson, which gives you the scientific foundation of what it is you want to do.

The Academy does not, however, tell us, nor should they, just how to go about it. So NASA then forms its own advisory committees, the Earth Systems Science Advisory Committee back here in 1983, which was an implementation committee. Now you know the science you want to do, how do you go about doing it? This is the Brotherton report, which I believe has been testified to in the past before this committee and others, in 1984.

The space station was proposed by President Reagan and included in the space station program were the polar platforms on which the Earth Observing System is to fly, and that has been a feature. The polar platforms are an approved program and they are under construction now.

NASA recognized back in 1984 that we were now getting to the point that we understood the science that we wanted to do and we set down mission requirements in order to proceed with that science. That in turn led into what is called a Phase A study. There are three parts to a NASA program. Phase A, you decide what the concept is that you want to do. Phase B, you get ready to define the thing in more detail, you figure out what the cost of it is going to be. And then you eventually enter into something called a new start, which is the Phase C/D.

As you will see later, we are in Phase B for this program. A new start will come, if it comes, in a few years.

The Academy continued to release reports and they fed into the whole process of the strategy study that the Brotherton committee

was putting together and the implementation studies that NASA was in turn doing. It was recognized throughout this that this was an international program and so various committees have been formed along the way to deal with the international issue.

CEOS is the first of these. The Committee on Earth-Observing Satellites uses the satellites from other countries. It was recognized that EOS, the polar platform program, was to be an international program because the space station was an international program involving both the Europeans and the Japanese, and so an international coordinating working group was formed on EOS to coordinate us with the Japanese and with the Europeans.

In 1986, President Reagan, acting on a Congressional resolution, proclaimed the International Space Year and put NASA in charge of that. And NASA recognized that one of the best things to do with that was to coordinate the study of the Earth. It is a natural for an International Space Year because it would involve all the nations of the world.

In 1986 the International Council of Scientific Unions approved something called the IGBP, the International Geosphere/Biosphere Program, which was a decade-long study starting in about 1991 and extending for many years, on how to study the Earth as a global integrated system, and it is recognized again in that you need the global perspective and space gives you the data to do that.

There is another international committee formed at this point, again to try to tie in the international aspects of this.

Throughout this study it was recognized that the data system that must be done for the Earth science missions, for EOS, for all of the Mission to Planet Earth, was the principal driver, so there is a whole separate effort that runs through this process in order to get the data system ready.

The data system runs throughout this and it comes down here, in November of 1988, to the actual release of contracts, Phase B contracts, to study the data system that has to be an essential component of this entire system.

At this point we are passing through Phase A into the Phase B study, but it was recognized that this is more than just simply observations from space. All the Federal agencies that do Earth science need to be coordinated in some way and the Committee on Earth Science, which is the coordinating body of all the agencies involved in earth science, was formed. In fact, there is a meeting this morning to continue the coordination of the study of the Earth.

I mentioned the Sally Ride report. In January we released an announcement of opportunity to select the instruments that would fly on the polar platform. We set down in April a year ago a strategic plan for the Office of Space Science which many of you have heard me testify to on other occasions.

I will not go through this in any detail here, but only to point out that when we prioritized the missions that Space Science would like to do we had AXAF, the Advanced X-Ray Facility, which was a 1989 initiative. You have in the 1990 budget before you CRAF/Cassini. And the highest priority next major mission for space science is the Earth Observing System.

As the International Space Year is going through this activity, NASA recognized that we needed to find a device for being able to coordinate all of the space agencies that would be involved in that, and in a meeting in New Hampshire last year the Space Agency Forum for the ISY was formed. Sixteen space agencies got together at the same time to decide how we can make the study of the Earth from space work. It is sort of an historic event. It is, to the best of my knowledge, the first time the 16 space agency heads ever sat down in one place together, and we have even been joined by more space agencies.

There was a meeting in Helsinki last summer which involved 23 space agencies from around the world. We are not dealing here with just the major space powers. We are dealing with the Brazilians and the Argentinians and the Austrians and so on. The Indians and the Chinese and Soviets all come together to plan how to do the International Space Year together and how to make it work to study the Earth.

In March of this year a panel of experts was put together to make recommendations to the Space Agency Forum for coordinating the activities and the essence of the activity is going to be, since the International Space Year is in 1992, to use it as an opportunity to do an assessment of the planet—what is the state of our knowledge about the Earth at that time?—and in the process of that begin to learn to use global data sets together, to practice with that activity so that when we get to the mid-1990s and we do something like the Earth Observing System or even more ambitious undertakings we know how to handle the data we get together.

If you ask how does this play in the International Geosphere/Biosphere Program, which is a decade-long multinational effort extending over many decades, the International Space Year culminates in 1992 with the International Geosphere/Biosphere Program which starts in 1991 and goes forward for many decades thereafter. So the International Space Year sets a benchmark for the International Geosphere/Biosphere Program which is to follow. All of this activity leads down an event in June of 1989.

Let me just say, to sort of wrap up where we are with this, you have the scientific underpinnings of a Mission to Planet Earth activity. You have a series of Academy reports, a scientific basis for what you want to do. You have the mechanisms for involving the international partners in this. You have committees like IFEOS and CEOS which are coordinating satellite observance from all around the world. You have the International Space Year, which is drawing in a lot of countries into those activities, particularly third world developing nations. You have the International Geosphere/Biosphere Program, which is going to use the data that this has provided over many decades to come.

And you have a NASA planning activity which is going through its normal routine of developing a mission from a Phase A to a Phase B study. And all of that culminates in June of 1989 in something that is called a non-advocacy review, and that is basically a standard NASA procedure for saying that we have been studying this mission for a number of years and now we are ready to present this as a budget issue.

We present it to a group which is made up of non-advocates, non-participants, who are to certify that the planning has been done well and the costs are in hand.

So June of 1989 is basically the beginning of the preparation of the fiscal year 1991 budget. We are bringing the planning process to completion here in June of 1989 so that it can be considered as part of the development of the fiscal year 1991 budget.

Now once more we are dealing here with the Earth Observing System that is part of the polar platforms. The attached payloads are in many cases duplicates of what is to fly on the polar platforms. They are also coming to planning completion this summer. Earth probes are similarly not as major an effort. They are coming to planning consideration in the summer.

The geostationary platform activity is a much different effort. That is still at a very early Phase A. It is a concept study. There are technical issues. There are scientific issues associated with the use of geostationary platforms. The geostationary platforms will not be an issue that we proceed with for some years to come.

The planning activity that is going on at the moment to bring this to completion for consideration this summer is the instruments to fly on the polar platform, the attached payloads to fly on the manned station, and the Earth probes focused mission. That is where we are.

[The statement follows:]

STATEMENT

OF

DR. LENNARD FISK

BEFORE THE

COMMITTEE ON

COMMERCE, SCIENCE AND TRANSPORTATION

UNITED STATES SENATE

Mr. Chairman and Members of the Committee:

Mr. Chairman, before I begin my testimony I want to take just a minute to put NASA's current planning on Mission to Planet Earth into proper perspective. You asked us to comment on NASA's timing and role in the implementation of the Mission to Planet Earth, including the scope, goals, objectives, and scientific value of the mission. The Mission to Planet Earth described in the "Sally Ride Report" was a very preliminary concept study of a possible future mission. No portion of the Mission to Planet Earth has been funded and the overall planning for the Mission is still very much at the conceptual level. With the exception of some preliminary study funds for the Earth Observing System (Eos) and Earth Probes, Eos and Earth Probes are potential new starts in the future as described in the Office of Space Science and Applications Strategic Plan. Even if NASA were to have funds, we are not technically ready to initiate Eos, nor is it clear that we would actually implement Mission to Planet Earth in its current conceptual framework. We have a lot of planning and studies yet to do before we could or should commit to such an ambitious and costly mission.

With that bit of background, I am pleased to have this opportunity to speak with you today about NASA's plans for a Mission to Planet Earth. Mission to Planet Earth was one of the four original themes suggested in what we now affectionately call the "Sally Ride Report", a 1986 report commissioned by NASA Administrator James Fletcher to provide strategy options for future exploration and utilization of space. Since the

publication of the Ride Report, the concept of a Mission to Planet Earth has been studied further by NASA's Office of Space Science and Applications (OSSA).

At the same time, there has been a growing world-wide awareness throughout the public and government that changes in our global environment may threaten the quality of life on this planet. To understand how the Earth system works requires the global perspective that only space can provide. In exploring the other planets of our solar system, NASA learns to understand these planets first at the global scale, because the only perspective we have of these bodies is that from space. This is opposite to how we have traditionally learned about our own planet, Earth, where our best understanding is at the local scale. The best perspective from which to obtain a global understanding of Earth is space, and at NASA we have a great deal of experience in studying the Earth and other planets from space.

Our current vision of Mission to Planet Earth is a research program that would consist of both space and ground elements. The space elements would include a series of Earth observing platforms, both small and large, in various orbits about the Earth, and instruments attached to the Space Station Freedom. The purpose of the space elements would be to gather long-term, global data sets on the surface and atmosphere of the planet. The principal ground element would be a data and information system within which we gather, process, and archive the data arriving from the space elements. The information archived in the data and information system would be accessible by the entire world-wide scientific community. The information would consist of global maps of surface temperature, precipitation, soil moisture, cloudiness, radiation budget, and other such global data sets required to understand the state of the Earth and any trends for change--just as we now use weather satellites to understand the state of the weather and trends for change.

This research program would also include surface science stations underlying satellite ground tracks, and various experiments using aircraft, balloons and rockets, underflying the satellites. These surface and sub-orbital platforms would provide in-situ calibration and validation of the remote-sensing instruments on the satellites and would conduct process studies on how the Earth works as a system so that scientists would know how to construct predictive models of how the Earth works as a system. Many of these surface and sub-orbital operations could be conducted by agencies other than NASA, e.g., NOAA, NSF, USGS and others who currently have roles in Earth research.

The Need for a Mission to Planet Earth

Why would such a research program be important to the nation? We have studied the other planets of the solar system from a global perspective, so why not our own? The reasons are compelling. A Mission to Planet Earth research program should be designed to understand the Earth as a global system, to determine the processes that create global environmental balance, to identify the processes that lead to change in this balance, and ultimately to provide the capability to reliably predict global change. It should also be a research program which responds directly to the needs of both researchers and policy-makers on the issue of global change.

There is concern for impending global change. The amounts of infra-red active trace gases in the atmosphere display significant increases since the beginning of the industrial age. There is significant ozone depletion over both poles of the planet. Observations from space document an alarming rate of tropical deforestation. All of these events may have implications for global effects on climate. Mr. Chairman, although there are great uncertainties associated with our knowledge of these processes, humans may be responsible for some of the environmental problems we are experiencing now through energy usage, fossil fuel burning, industrial activity, and land and agricultural practices. Unfortunately, we do not know the relative contribution of human and natural processes to these changes. Thus, we as humans bear a responsibility to provide an understanding of the consequences of our utilization of the Earth, and to understand the potential impact on the environment. The consequences may be considerable on agriculture, energy and human health. Global change can lead to a significant change and redistribution of global resources and economic potential.

The problems of global change are complex. Many are at present beyond our current understanding. The greenhouse warming is one of these. The facts are simple: the concentrations in the atmosphere of many infrared active trace gases are increasing rapidly. Simple physics tells us that this will cause a global warming, but the question is by when and by how much? We answer questions like this by constructing physical models of the climate system. The best we have today are called Global Circulation Models, or GCMs. They are dependent on proper mathematical descriptions of the coupling of the atmosphere to the land and oceans; specifically the fluxes of heat, moisture and momentum between the atmosphere and the surface. In short,

the GCMs require an understanding of the how the Earth works as a global system. Today, in the absence of this total knowledge, the GCMs we construct are approximate and inaccurate.

Present day GCMs cannot be expected to be able to predict the magnitude and timing of any global warming with any degree of accuracy. Yet, the answers to these questions are important because these very same models predict severe effects for even a mild global warming, i.e., significant changes in rainfall and severe weather patterns, mid-continental drought in the U.S., and an increase in global sea level. The impacts on agricultural productivity, energy and water resources, and on human health are manifest. The consequences predicted by theses models are too damaging for their present inaccuracies to be acceptable. Different GCMs differ by 50% in the predicted temperature rise for a doubling of atmospheric carbon dioxide (CO_2), and by a factor of two for predicted changes in precipitation. The models differ even more when attempting to predict regional and seasonal climate changes, showing very different changes in regional soil moisture in the United States for a doubling of atmospheric CO_2, and differing even in sign for predicted seasonal precipitation changes.

The models fail because our knowledge of Earth processes is insufficient. The modelers are not yet able to include major feedback effects properly, effects such as the role of terrestrial vegetation in pumping moisture into the atmosphere, the role of the ocean in regulating atmospheric CO_2, and the effects of clouds. Clouds can either warm or cool the global climate. Low clouds reflect sunlight and tend to cool the Earth, while high, thin clouds let the sunlight through but trap the returned infrared radiation and thus warm the planet. Recent analysis of data taken by NASA's Earth Radiation Budget Satellite, and of Earth radiation budget sensors on the NOAA-9 and NOAA-10 satellites, shows that the effect of clouds in April, 1983, was to cool the Earth by approximately 15 degrees Centigrade, or about three times the amount of warming predicted for doubling atmospheric CO_2. It is not clear at all, with today's state of knowledge, what the effect of global warming will be on clouds, and thence back on the warming itself. Cloud radiative feedback is sufficiently robust to totally cancel or to aggressively magnify any global warming.

What is required to answer these scientific questions and to make the models adequate for our needs for predicting future global change? The answer is a coherent research program designed to understand our planet, how it functions and how it changes over

decadal to 100 year time scales. An accurate predictive ability is essential for making sound policy decisions in an era of global change. The potential changes touch every area of human productivity and carry a large economic penalty. The consequences of a headlong, ill-informed rush into policy could be disastrous.

Mission to Planet Earth, the U.S. Global Change Research Program, the International Geosphere/Biosphere Program, and the International Space Year

At NASA, the term "Mission to Planet Earth" has come to mean the space observation platforms, data and information system, Earth process studies, and global Earth system models required to understand the global environmental system and its changes. However, this concept is part of the larger U.S. Global Change Research Program, which in turn contributes to an international scientific plan of global research organized by the international Council of Scientific Unions (ICSU) and called the International Geosphere Biosphere Program (IGBP). The U.S. Federal Agencies have come together under the auspices of the Committee on Earth Sciences (CES) to define the U.S. Global Change Research Program together with roles for each of the agencies. As you know, Mr. Chairman, this program was outlined in a report entitled, "Our Changing Planet: A U.S. Strategy for Global Change Research" that accompanied the FY 1990 budget. NASA has an important role in the U.S. Global Change Research Program, which is to provide the long-term, global observations from space and the associated data and information system that are essential for understanding the Earth, for detecting global change, and for validating a new generation of predictive GCMs.

The problems associated with global change are clearly global in nature, and while many observations can come only from space, NASA alone cannot do it. Remote sensing data from space requires complimentary ground-based studies for validation and for focused process studies, and these studies must be conducted in many places around the world. The cooperation of many countries will be required under the auspices of the IGBP. Fundamental studies of physical, chemical and biological processes of all kinds are required. The talent and resources of the seven CES research members (NASA, NSF, DOT, DOC/NOAA, EPA, DOE, and USDA) will be needed to address these complex research issues. For example, the U.S. Geological Survey and the NSF can provide studies of the Earth's past climate from paleontological studies and from ice sheet cores. These paleoclimatic data are invaluable for testing the validity and robustness of modern GCMs.

There are many government agencies and international scientific societies that must work together in order to understand our planet and what we may be doing to it. However, at the heart of all these efforts--essential to their success-- is the global data set on the Earth and how it is changing. This Global Data Set can only be provided from space by the spacefaring nations of the world. Some 23 of the national space agencies of countries around the world have formed, under NASA leadership, the Space Agency Forum for the International Space Year (SAFISY) to coordinate International Space Year (ISY). NASA, which has the responsibility for the ISY in this country, has been encouraging the ISY to give particular emphasis to the study of the Earth; not only space observations but also complimentary ground-based studies by all nations of the world which have space activities. The ISY culminates in 1992, and will provide the lead-in to the era of the 1990's when the IGBP and major national programs in global change will begin.

NASA's Preparations for Mission to Planet Earth

Global changes in the atmosphere and on the surface of the earth have already been observed, and the impact of these changes is uncertain. We now have the ability to observe the earth from space as a system, and we have the technology and scientific expertise to tackle Earth system science. There is a world-wide awareness of the problem of global change, and international and interagency cooperation is growing. There is a growing public awareness of changes in the global environment that demands attention, which creates the opportunity to demonstrate U.S. leadership in an area where every citizen of the world will ultimately benefit.

NASA currently has a strong program in the Earth sciences that could build to something like the components of Mission to Planet Earth in the 1990's. The Earth Science and Applications Division in the Office of Space Science and applications has an extensive Research and Analysis program, which primarily funds the university community, combined with a suborbital program of experiments using aircraft, balloons and rockets, to study a variety of Earth processes. In addition to the suborbital platforms, we are developing a number of scientific instruments for flight on the Space Shuttle, Space Station Freedom and free-flying satellites. These instruments will conduct focused Earth studies in preparation for the future space components. Several older spacecraft are still collecting global Earth data including Nimbus-7 and the Earth Radiation Budget Satellite.

We use all of these programs in a coordinated effort to understand our environment; a good example is the Upper Atmosphere Research Program (UARP), a program supported by the U.S. Congress. The UARP was motivated by concern about global stratospheric ozone reduction. When the mechanics of ozone depletion were first identified in the early 1970's, the predictions of likely global depletion during the next decade varied widely. For the first decade of work on the problem, our state of understanding and the quality of the measurements were inadequate for any compelling base of action.

In the first years of research, there was a lack of data on the problem, no validated models for prediction of future effects, and large uncertainties in both data and models; a situation exactly similar to other problems of global change today. After years of research, a long-term set of quality data was acquired, the processes operating to produce and destroy the ozone layer in the atmosphere became better understood, and the models became more consistent in their predictions. The existence of the UARP allowed rapid response to the discovery of the Antarctic ozone hole, and the capabilities built into the program allowed for the timely analysis that showed the chlorofluoromethanes (CFMs), along with the peculiar polar meteorological dynamics, to be responsible. Even before the Antarctic ozone hole became a public issue, it was possible to reach international accord on voluntary industrial action for reduced production of CFMs because of an international scientific consensus based on confidence in validated model predictions.

There are several lessons learned from the ozone issue that apply directly to global change. Space-based data on global change problems, including ozone depletion, are essential. A long-term program of sustained research is essential. There must be time and resources for an intense program of research along with sustained, consistent global observations in order to reach mature scientific understanding. That scientific understanding is necessary in order to reach international scientific consensus on the timing and magnitude of the future effects, and therefore predictability which is the foundation of a prudent, acceptable policy.

The history of global warming and other global change will be similar. Today we have speculations, but they are based on the predictions of inadequate and incomplete models, and there is no set of validated global data with which to test such models. Experience with the ozone problem clearly shows that we should

not, nor expect to, make dramatic changes in economic policy in this situation, but rather what is needed is sound, credible, consistent research which yields reliable predictions that can be verified by data. It is only through such research that a compelling case for appropriate action can be made. The burden of proof for scientists is greater in the greenhouse warming problem than for ozone depletion because the consequences of dealing with the problem are so much greater; it is one thing to remove the CFCs from the economy, it is quite another to reduce fossil fuel consumption.

NASA currently has under construction three satellite projects which will provide important data on global change. The Upper Atmospheric Research Satellite (UARS) scheduled for launch in 1991 will provide definitive measurements of the chemistry and dynamics of the upper atmosphere and provide for a complete, global set of atmospheric data for the Earth's ozone layer. Topex/Poseidon is a joint project with France to measure with great accuracy the height of the world's oceans, from which global ocean circulation can be inferred. It is scheduled for launch in 1992. The results from this mission have a strong relationship to those of the NASA Scatterometer, which has been selected preliminarily for flight on the Japanese ADEOS satellite in 1994, and which will measure wind stress on the ocean surface for determination of ocean currents. These projects address the coupling between the oceans and the atmosphere, which is key to understanding how the two principal systems of the Earth's climate operate together.

Each of these missions attacks a focused problem important to understanding our global environment. They do not, however, deal with the Earth as an integrated system. We need to observe the component parts of the Earth simultaneously to achieve an integrated understanding of how the atmosphere, ocean, ice and biosphere interact and operate as a system.

The Current Conceptual Architecture of the Mission to Planet Earth and Its Relationship to the U.S. Global Change Research Program

Although a Mission to Planet Earth is still just a conceptual study, NASA has begun advanced technology development studies for the Earth Observing System (Eos). If approved, this will be an important part of NASA's contribution to the U.S. Global Change Research Program. Eos is a suite of remote sensing instruments that could be flown on the U.S. Space Station Freedom polar platform.

However, NASA does have a conceptual model of the Mission to Planet Earth architecture that we are using for internal planning purposes. The current Mission to Planet Earth concept consists of four major types of space components. Again, none of these components are currently funded, nor is it clear that we would actually implement Mission to Planet Earth in its current conceptual framework.

1. Earth Observing System/Polar Platforms (EOS):

There are four large polar orbiting platforms, two of which are provided by the international Space Station Freedom program--one by the U.S. and the other by ESA. The U.S. platform would be launched in late 1996 and the ESA platform approximately two years later. A second U.S. platform and a Japanese platform would make up the remaining part of the total Earth Observing System (EOS). These platforms are planned for a 15 year observing program for each of the four satellites in order to obtain long-term, consistent sets of global Earth data on a wide-ranging number of measures of the state of the global environment. These platforms are the key elements of Mission to Planet Earth and the first elements to be deployed.

NASA has been developing the EOS concept since 1983, and has recently completed selections of science instruments, instrument team leaders and team members, and interdisciplinary scientists from an Announcement of Opportunity (AO) released in January, 1988. Several Phase B development contracts have been issued for design of various facility instruments. Goddard Space Flight Center has management responsibility for the first U.S. platform, and the Jet Propulsion Laboratory would have management responsibility for a second U.S. platform.

2. Space Station Attached Payloads:

These are instruments intended to be attached to the U.S. Space Station Freedom for special studies from low inclination orbit. These studies include the role of tropical oceans in climate, and the study of the diurnal variability of some important global processes such as precipitation. These payloads will also be deployed early in Mission to Planet Earth and will be chosen later this year as part of the EOS AO process.

3. Earth Probes:

These would be a series of small free-flying satellites for special Earth studies not possible on the polar orbiting platforms. They require special orbits or spacecraft, and can be done with relatively inexpensive spacecraft and small launchers. Examples include a Tropical Rainfall Mapping Mission (TRMM), if the instruments are not flown as attached payloads; a Geopotential Research Mission (GRM) for determination of the Earth's geoid and support of the Topex/Poseidon and EOS altimeter measurements; and a Magnetic Field Explorer (MFE) for study of the earth's interior structure and motions. Also in this category is continuation of the Total Ozone Mapping Spectrometer (TOMS) global ozone measurements in anticipation of the failure of the Nimbus-7 instrument.

4. Geostationary Platforms:

These would be five platforms in geostationary orbit for complete, simultaneous coverage of the Earth's globe at any one time. The conceptual plan calls for 3 U.S., 1 ESA and 1 Japanese platform. The geostationary platforms complement the polar platforms by providing continuous synoptic (snapshot) coverage of the entire Earth with high time resolution for studies of processes that have significant diurnal variation and for singular events. These platforms would arrive late in the Mission to Planet Earth program, with a new start in the mid 1990's and a first launch at the end of the century.

The central component of Mission to Planet Earth is the Earth Observing System Data and Information System (EOSDIS). This system provides for central receiving, processing and archiving of the data from the space elements of Mission to Planet Earth. Its initial implementation will be completed for EOS, the first space element. We have two competitive Phase B studies funded for the design of the EOSDIS.

The information resident in the EOSDIS will be used by scientists all over the world to conduct research on Earth system science and global change. Global-scale Earth system models will be constructed, the descendants of today's GCMs, and will be tested

against the long-term, global data sets in the EOSDIS. These models will incorporate information on Earth system processes that result from Mission to Planet Earth research and analysis programs. The ultimate product of Mission to Planet Earth will be validated global, interactive Earth system models with the ability to predict future global change to an accuracy sufficient for future policymakers.

Summary

Again, Mission to Planet Earth is still just a NASA internal concept study. It is clearly not part of the current U.S. Global Change Research Program, nor is it clear that we would ever implement it in its current conceptual framework. However, if it were to become a NASA initiative, Mission to Planet Earth could be the largest scientific undertaking in NASA history.

Due to the global nature of the problem this research effort addresses and the interest of most of the world in the goals of this effort, Mission to Planet Earth would require cooperation and cost-sharing by many of the major spacefaring nations of the world under the leadership of the U.S. The benefits, however, are many:

1. A critical investment in preserving the global environment, and in providing the information required to cope with the potential for future global change.

2. Utilization of the U.S. investment in space research for a purpose which everyone can see and appreciate, and for providing direct benefit to the citizens of the U.S.

3. An international effort in space demonstrating U.S. leadership, and with the potential to motivate additional commitments to this effort by both our economic summit partners and the Soviet Union.

4. Demonstration of U.S. commitment to investment in a better global future with benefits which accrue to everyone, in particular the next generation.

5. An idea which stirs popular ideals, continuing the inspirational tradition of space activities.

Mr. Chairman, we at NASA have many goals. We observe the universe in ever increasing resolution and sensitivity, ever trying to define our place in the cosmos. We send missions to the other planets in our solar system, trying to understand the origins of life. The time has come when we should mount a mission to Earth--clearly the planet we care about most--to try to understand how to sustain the development of life on our own planet.

The CHAIRMAN. Very good. Does that conclude your statement, Dr. Fisk?

Dr. FISK. Yes. Thank you very much.

The CHAIRMAN. Now we are all organized. We have got Dr. Sally Ride, Dr. Anderson and Dr. Fisk to lead us and we have succeeded and it is 20 years hence. Dr. Ride, what have I got? You know, there are a lot of hurdles in there I want to ask about—the jurisdictional, the international, the apportionment of the international, the cost. But let us assume we have done all of that.

I want to find out what have I done. I have gotten a comprehensive global change research program in place, a Mission to Planet Earth in place. Then what can we expect from that? What do we have, in your opinion, having succeeded?

Dr. RIDE. I think we have a few things. First of all, we have a system in place that has been gathering data for two decades and will be able to continue collecting data for many decades to come. This is not something that stops in ten years of 15 years but what we would assume would be a system that would be in place for many years.

With the data that we had collected during the first 20 years, we would certainly expect to have been able to significantly improve our models of all the Earth processes, and we can take maybe weather as a good example of that. We would expect to have a much better model for weather prediction and I think that the implications of that are fairly obvious.

We would like to have similarly good models for the other Earth processes and we would have the data over a sufficient period of time that we would have some confidence not only in the fact that the models described what we had seen over the 20 years but also that the models might be able to predict what we would expect to see over the next five, ten, 15, 20 years.

And that is, I think, the most significant contribution of the Mission to Planet Earth system, is that it will give us the ability to understand how an El Nino this year affects weather next year or five years from now, how volcanic activity affects weather or climate, the atmosphere, one year from now, two years from now.

It will give us a sense of how each thing that we observe with Mission to Planet Earth and then feed back into the models that have been generated through Mission to Planet Earth will affect our lives and the conditions on the planet.

The CHAIRMAN. I take it it also will improve our entire space program. I am trying to be, in a sense, the devil's advocate. Somebody will come around and say why in the world are going to spend $24 billion to find out about the weather?

Dr. Anderson, do you have any comments, and then Dr. Fisk? What do we have, let us say, if we have succeeded and we have done all these things that Dr. Fisk has outlined in detail and we have coordinated the jurisdictional problems and we have coordinated the international effort, and we have got the space station and we have a comprehensive Mission to Planet Earth in place, 20 years hence?

Then what do I have? What have I bought?

Dr. ANDERSON. As Dr. Ride mentioned, we would have two decades of continuous and simultaneous observations of a large

number of parameters dealing with the total Earth system, something we have never had before. We should be able to make predictions about not only the climate and about things that you can measure from orbit and ground observatories but also from the geological record.

Let me back off a little bit and talk about things that we are not going to learn from the NASA part of the program or from the orbital part of the program, but from the basic research part of the program. While we are gathering this information over the next two decades and have a pretty good idea of what influences the various parts of the system, we will also be doing research in the geological record and seeing how, for example, volcanic eruptions, magnetic fields, climate and so on have changed over the surface of the Earth in the past.

We have a very limited record and will have a very limited record even after this Mission to Planet Earth is going on, so we need the complementary ground-based and geology-based observations. For example, are there global warmings in the geological record long before the industrial revolution? What factors other than CO2 and fluorocarbons in the atmosphere cause global warmings or, for that matter, global coolings? What caused the ice age?

What kind of variations have we had in the Earth's climate? What do continental drift, plate tectonics and volcanic eruptions have to do with the oceanic circulation and the climate circulation?

What I am saying is this. We need simultaneous long-term orbital observations in conjunction with many ground-based observatories all over the world so we can measure the parameters as they will exist over the next 20 years, but we also need this very intensive look into the geological record so we can put this little snapshot of Earth history into the broader context of the Earth.

I think at the end of 20 years, while we are still exploring the planets and still learning about other worlds, and as we study our own Earth intensely and then look at the geological record of our own Earth, we will be able to understand what causes what, what affects what, and to some extent, make predictions.

For example, it has been mentioned that droughts and global warmings and El Ninos and oceanic circulation are somehow all involved with each other. We are recently finding out about huge underwater volcanic eruptions and lava flows in the eastern Pacific. They probably caused a lot of earthquakes. These earthquakes and these large lava flows may have something to do with the pattern of El Ninos and the El Ninos in turn affect the global circulation of the atmosphere.

So we have to get down on the ground and look inside the Earth as well as look outside in order to couple the whole Earth together. I think in 20 years we will probably understand the Earth very well indeed.

The CHAIRMAN. Dr. Fisk?

Dr. FISK. Just briefly, I would say that if we have succeeded with this we have given the sound scientific basis for policy decisions that need to be made.

There are some interesting analogies here, I think, that are worth noting, perhaps in the ozone problem. If you look at ozone depletion when it was first suggested and detected in the mid-

1970s, our scientific understanding of the magnitude of the problem, its long-term trends, and its true causes, was really relatively primitive and there was a lot of variability in the predictions. The scientific basis for compelling reasonable policy action was not there. It is there today, and we are seeing considerable action on the problem.

The same thing will probably happen in the long-term environmental changes. Our understanding of causes of global warming, the time scale over which it could occur, the regional effects are simply not there at the moment, and as a result of that I suspect it will be very difficult to have policy changes that are compelling.

So there is an urgency. There is a need to assemble that understanding to therefore serve as the basis for sound policy decisions. And if we succeed we will provide that understanding.

The CHAIRMAN. I do not know whether you had a chance in the "Time" magazine to see Isaac Asimov's article. He parallels our situation today with back in the post-Civil War era and how we came together as a nation because we had the West to explore and that challenge brought us together. If we could get, let us say, the Mission to Planet Earth, perhaps saying we could move to recouping from the sun an energy source in space to serve all nations and thereby bring about cohesiveness and peace in our time and those other things.

Is that fanciful or can we get more than just accurate measurements and figures? Can that, in your imagination, Dr. Ride, bring us to something other than a better weather report?

Dr. RIDE. I certainly hope so, because that would be an expensive weather report.

I have not read the "Time" article or have not read it recently, so I could not comment specifically on what Dr. Asimov wrote about. But I think that there are maybe two points to be made here.

One is that there will be, I think, significant economic benefits or economic implications of a Mission to Planet Earth, and although we are using the accurate weather reporting a little bit tongue-in-cheek this could be an extremely important thing, to be able to predict significant droughts, unusual rainfall, for obvious agricultural reasons.

It is very important to know, for example, how the concentrations of fish are being affected in various areas of the ocean, just for the fishing industries. And there are a whole set of economic implications that could come out of this.

I think the other important point to be made is that we do not know what we do not know yet, and we have not studied the Earth sufficiently to know what are all the effects that we are having on the Earth itself. What effects are we having on the environment and what are the implications of those? What are the secrets that the Earth still holds that we have not uncovered yet?

Until we do something like a Mission to Planet Earth we are not going to know. So there may very well be some of those surprises, some of which we could turn to our benefit, some of which maybe if we do not know about we will be in a significant amount of trouble. So I think that we do not know what we do not know, and in this area there is a lot that we do not know.

The CHAIRMAN. I am going to use the clock on me to begin with and, Senator Gore, you can take your time because we had quite a few members that had to go to other committee meetings.

Specifically, Dr. Anderson, you had emphasized the jurisdictional difficulties. You know, I get that frustration of the captain who waits for his ship to be fit and never puts to sea. If we ever await jurisdictional harmony, we are gone. We will be dead and gone.

The Global Change Research Act, S. 169, is an effort to try to surmount this particular difficulty. Do you endorse that bill? Do you have any criticism of it or any changes to suggest? We would be delighted to hear from you on helping us to get the Federal Coordinating Council coordinated, as you indicate with all the different entities that are interested. Also you can see in Dr. Fisk's presentation the outline of all of the efforts that have been made.

It would just be terrible if we just made all of that effort, you from the scientific side and we from the political side, just to run around and do nothing. Have you seen this bill?

Dr. ANDERSON. No, I have not seen it, but I endorse efforts to have good interagency coordination. But I also endorse the idea that you cannot wait until all these jurisdictional problems are taken care of, because there are some clearcut things that NASA can do by itself that NOAA can do by itself, that NSF can do by itself, if they are adequately funded.

The CHAIRMAN. If you three told us what to do, I think we could get it done. But unless you tell us we will have a problem. If I am going to have to tell those on the Government Operations Committee or tell somebody else on the Environment and Public Works Committee, then I think that will end it. Rather, I would like to have a group like yourselves present to the Congress an outline of the necessary procedures. That's why we have asked for the Federal Coordinating Council to submit a global change research plan.

But if you have any suggestions along that line, it would be of tremendous help to us. I think we are all ready to move and, as I say, Dr. Ride's report in particular sparked our interest and focused attention on this particular problem and that is the time we can get things done. We do not want to dissipate it.

Let me yield to Senator Gore.

Senator GORE. Thank you very much, Mr. Chairman.

First of all, just a philosophical note on the presentation. I have no quarrel with any of it, but as someone who has worked on the global warming problem for eight or nine years now I am very sensitive when people who are arguing for research programs, which I strongly favor, come up to the edge of saying we do not now know enough to act on the basis of the information we already have about global warming and global change.

Dr. Fisk, you said that in the 1970s, when the ozone depletion problem was first discovered we did not have enough information to serve as a basis for action. I know you did not intend to be heard this way, and I am sort of speaking to the record, not in contrast to you, but it is an important point, I think.

I think we did have the basis for action when Drs. Roland and Molina discovered in 1974 that the insertion of 800 million tons annually of chlorine-bearing substances directly into the stratosphere would have the expected consequence for the ozone layer. I think

we had the basis for action, but it was not translated into action because of failures on the part of those of us who should have paid attention and heard what they were saying.

The second point from that example. There were indeed uncertainties in the model that Molina and Roland used, and they were in fact wrong. They significantly underestimated the extent of the problem. And there are good reasons for believing that the uncertainties which exist with the current predictions of global warming are on the down side as well as on the up side.

Just as the polar stratospheric clouds above Antarctica provided a positive feedback loop that the models of the 1970s did not encompass, the relationship between warmer oceans and CO_2 absorption may provide a positive feedback loop on global warming that we do not now calculate, or warming tundra and methane, or increased ultraviolet B flux and phytoplankton fixation of carbon in the oceans, and a half dozen other potential magnifiers that could make those predictions of global warming inaccurate on the optimistic side.

In any event, I just wanted to make that point because I am as strong a supporter, with the possible exception of the Chairman of the full Committee, of this program as you will find in the Congress. But I do not want anybody to get the message that we need this before we act to deal with global warming. I think we know enough now. As I say, I am not picking a bone with you. I just wanted to make that point for the record.

Now, could you put that graph back up, the one that showed the Earth observation platforms and so forth, the one with the pictures?

[Slide.]

Senator GORE. That is the one. Now, you have that arrow between the global data and information system going down to the global interactive models, and then you have the arrows from the models to the process studies and to the assessment and prediction block. Right?

Dr. FISK. That is correct.

Senator GORE. All right. When the program reaches maturity, how many bits of data are represented in those arrows? How many gigabits? How many billion bits of information per second?

Dr. FISK. Let us see if I can remember the number. I may have to correct it for the record if I get it wrong. If you look at all the data that Mission to the Planet Earth could produce over its 15-year lifetime, you are talking about 12,000 terrabytes. That is the number I keep in my head.

Of course that gets digested.

Senator GORE. Now wait a minute. Explain a terrabyte. Is that a trillion thousand bits? What is it?

Dr. FISK. Somebody help me out here.

Senator GORE. A byte is 1,000 bits; is that right? What is a byte?

Dr. FISK. It is 1,000 gigabits, 10^{12}.

Senator GORE. 10^{12}.

Dr. FISK. It is a 10 and 12 zeros.

Senator GORE. Now contrast that with the number of bits of information that we currently have in the earth sciences program.

Dr. FISK. My recollection is that if I take the National Space Science Data Center at Goddard as representative of the accumulated data that we have to date—now that does not include a lot of earth science, but it is a representative number—it is about 5 or 6 terrabytes. So this is somewhere in the neighborhood of 2,000 times the current amount of data in the National Space Science Data Center.

Senator GORE. Okay. So the amount of information measured in bits of information will be 2,000 times greater than the data base and the data flows we are currently dealing with?

Dr. FISK. That is probably a reasonable estimate, yes.

Senator GORE. Now I saw a presentation by somebody at the Planetary Society that represented that on a logarithmic curve that made it seem even larger than that. Is it fair to say that the single most troubling, difficult, daunting task in the entire Mission to Planet Earth program is dealing with the data once it comes down from Earth orbit?

Dr. FISK. That is an accurate statement. It has been an issue that we have tried to address since the beginning of the program. If you recall that chronology chart there, I tried to single out on that that the data activities have led the whole program.

We defined the data requirements as part of the beginning of this activity. When we passed from Phase A to Phase B, it was the data system that passed first because it is the one that has to be right in order for this to succeed.

And when we talk about what we will bring to planning readiness this summer, it is the instruments that are to fly on the Earth Observing System, it is the data system that is to handle that, including the fact that we are going to have to assemble a facility—in this case at the Goddard Space Flight Center—and that facility is going to have to house the kind of data that we anticipate getting. It will have to have the necessary storage.

You know, you have to do optical disk storage of these activities. I think it takes more magnetic tapes than exist in the free world in order to be able to accommodate this data. So it is not that it cannot be done, but it has to be done right.

Senator GORE. More magnetic tapes than currently exist in the entire free world?

Dr. FISK. I believe that is correct.

Senator GORE. I am not so much worried about the storage as I am about the processing and the data flow between these boxes you have here. Most computer links now have flows of around 50,000 bits of information per second.

Supercomputers that transfer graphic images that are changing over time sequences need data flows above a billion bits per second, 3 billion perhaps.

Yet I am told that the data flows that will be involved in this program will have surges of up to 20 billion bits per second. Now, we do not have any switches or cables or programs—least of all, programs—to deal with information flows of that kind.

Dr. FISK. I am not sure of the source of that comment, but let me just sort of run through the sequence of how this data comes down. The Earth Observing System, which will give you the bulk of this data, these polar platforms are off in the future some place, is scaled to work with the existing TDRSS system of NASA.

Launched in the next few weeks is the third of the TDRSS satellites, so TDRSS will track these polar platforms and the TDRSS system will pump the data down along existing links—White Sands to the Goddard Space Flight Center.

What happens is, of course, you are doing this relentlessly. You have a certain bit rate for the satellite in orbit, which is all scaled, but it just continues to produce a large amount of data, which is accumulating now in your data storage system like Goddard, or will if the program goes forward.

Senator GORE. Most of what we get now is not ever analyzed, is it?

Dr. FISK. In the case of atmospheric data, the analysis rate is close to 100 percent.

Senator GORE. But most of the data that is coming from the satellite data collection system is not being analyzed, is it, Dr. Ride?

Dr. RIDE. I have some, maybe limited perspective on that. I know that, for example, if you look at the earth radiation budget satellite which is in orbit now, which I am familiar with only because I had the chance to deploy it from the shuttle on my second mission and have since visited some of the people that are analyzing the data. We deployed it in October of 1984 and it became operational along with a couple of other NOAA satellites in the system within a few months of that, so it has been collecting data for three to four years now.

I just recently saw the first paper that I had seen published on the data. It is probably not the first paper, but it is a paper published from the data just recently in Science Magazine just a couple of months ago, and I have talked to some of the people who have tried to analyze the data from ERBS and they are facing a problem that is not unique to ERBS and is not unique to earth information systems or earth observing systems, that the data is very difficult to calibrate.

It is very difficult to process, and this particular group that I have been talking to have spent over a year just getting to the point where they had a good calibration of the data before they were ready to even analyze the information, and I think that speaks to the problem that you are addressing, that we really need to get better at getting the data from all of these satellites down and into the hands of scientists in a usable fashion, and I think that is one of the challenges for the data system with Mission to Planet Earth.

Senator GORE. Yes, the staff informs me that only a small percentage of the overall satellite data being collected today really gets analyzed in detail, and one of the points I am trying to lead up to is that if we go about this in a careful way in the Committee in allocating our time and attention and effort, a very large percentage of it needs to go to this data problem.

I have been advocating a fiber optic network with very high data flow capacity between supercomputing centers and advanced computing centers, massive parallel computers, et cetera. That is why I was getting at these arrows between the bottom three blocks.

Once you get your data, let us assume that you find a way to deal with all this data; that you find a way to calibrate it, process it, store it, present it in a fashion that makes it accessible for the

modelers and the process studiers and those who are making assessments and predictions. Then you anticipate lots of teams of researchers at universities around the country running studies on this data, correct?

Dr. FISK. That is correct.

Senator GORE. Now, that means that you are going to have to have graphic images with time sequences going back and forth between the computer that takes the data from earth orbit and all of these computers around the country with teams of researchers clustered around them studying it, correct?

Dr. FISK. That is correct. In fact, in the selection of the experimenters for the Earth Observing System which was just announced, there is a whole series of interdisciplinary teams which were selected as part of the mission, and you are correct on the intention of that.

I may be mistaken, Senator, but I am not sure that aspect will burden the system in the sense that if you have succeeded in the problem that Sally mentioned, which is taking the data, reducing it to usable physical units that you can deal with, which is done in a centralized facility, particularly since you are looking for change—I mean, that is the issue you are always looking for so you need a series of these—you reduce this to physical images and to graphs. Pictures are the most useful things. Then you have to be able to transmit that to your interdisciplinary teams around the country.

Senator GORE. There are no switches. There is a redundant capacity along some data highways, but what they call the last mile is not there. The switches are not there. The programs are not there. It is not in the preliminary budgets that I have seen. I think that we have got a lot of work to do there.

As we set about it, who do we go to? Do you recommend a new entity be established for the management of this program?

Dr. FISK. Let me make sure I understand the question. Mission to Planet Earth as a whole?

Senator GORE. Yes, as a whole.

Dr. FISK. No. I think, and I say this having given a considerable amount of thought to the subject, that you are involving here a variety of different federal agencies and a variety of different international space programs.

Let us take the U.S. alone as the issue here. You need two things. You need a clear set of understandings as to what the mandate and responsibilities of each of the agencies involved is.

In the case of NASA it is really quite simple. We do the space aspects of this thing and we bring the data down. We make it usable, and we do through our normal process involved in the modeling. The NSF I think can be defined simply. That is the ground-based studies, the basic research. NOAA has a clear role through its operational satellites. You need to specify sort of agency by agency what the role is.

Senator GORE. But who is in charge?

Dr. FISK. I do not think it is necessary.

Senator GORE. You do not have to have anybody in charge?

Dr. FISK. I think you have to coordinate.

Senator GORE. Who coordinates it? The Commerce Committee?

Dr. FISK. There is no—the Committee on Earth Science?

Senator GORE. This is the Commerce Committee. There most certainly is a Commerce Committee.

The CHAIRMAN. The answer is yes.

Dr. FISK. I think of it as the Science Committee. The Committee on Earth Science. It has so far been effective. This is a committee of the Office of the Science Adviser to the President, OSTP.

Senator GORE. So OSTP is going to be in charge of this?

Dr. FISK. I think the Committee on Earth Science is going to produce the coordination among the agencies, if the roles for each and every agency are clearly set out.

Senator GORE. Who is the head of the Committee on Earth Science now?

Dr. FISK. At the moment it is Dallas Peck who is the Director of USGS.

Senator GORE. So the Director of the U.S. Geological Survey is going to be in charge of this?

Dr. FISK. I think you are overemphasizing what it means to be in charge of. I think NASA needs to be clearly in charge of NASA's portion of the program, and NSF needs to be clearly in charge of its portion of the program.

Senator GORE. Okay. Who is going to be in charge of the data links that I have just talked about? I mean, we have agreed that that is the single most difficult part of the entire mission by far. Who is in charge of that?

Dr. FISK. NASA.

Senator GORE. NASA is?

Dr. FISK. If we are shipping our data around the country as we do now, we are responsible.

Senator GORE. What part of NASA?

Dr. FISK. There are two aspects of it: The Office of Space Operations, Code T, is responsible for the ground links that NASA maintains. At the moment it is the PSCN, the Physical Science Communication Network, which operates around the country for linking the universities that receive the data from NASA missions.

Senator GORE. Okay. So if I am at the University of Tennessee in Knoxville and I have got a team of researchers that is attempting to interpret the data on volcanoes that is coming from the global interactive model that is set up as part of this mission and I am having a problem working out the computer program in getting a coordinated flow of data, then I go to the Office of Space Science at NASA?

Dr. FISK. Yes, if you like. Now, I mean, these networks are highly intertwined, as you know. We even make use of NSF network ourselves, which is—there is an NSF network hooking supercomputers together. But I think the point is that if this data analysis is being done with NASA data—it is part of our interdisciplinary team, for example, that we selected as part of the Earth Observing System—we have the responsibility, and we have had for some time and continue that responsibility of getting the data to that team.

Senator GORE. Well, with all due respect, I really think this needs a lot more analysis because my experience, limited as it is, tells me that a complicated program in order to be successful needs somebody managing it, needs somebody in charge of it.

Management by a loose confederation of agencies that are often trying to push budget line items into somebody else's allocation, who are often fighting with each other for personnel slots and all kinds of other things, that is just a prescription for disaster, it seems to me.

I do not know who ought to be in charge of it, but I know somebody ought to be in charge of it and it ought to be coordinated, and we ought to be able to, as a Committee, have somebody come up here and tell us that they have made an assessment of the entire thing.

We should not have to go to 10 different agencies and pull it together ourselves, or ask the head of the U.S. Geological Survey, who has a part-time assignment heading a committee for OSTP, to do a full-time job. I mean, I think this is a major problem.

Dr. Anderson, did you want to comment on that?

Dr. ANDERSON. I agree absolutely. What we saw on the viewgraphs from Dr. Fisk is just a very, very small part of this program. The Mission to Planet Earth he has in mind is just the orbital part, the atmosphere and a little bit of the ocean, and very, very little of the rest of the Earth. We cannot understand the Earth if we study only a piece of it.

As far as having NSF in charge of the ground observatories, with the disparity in budgets, that clearly would not work. As long as NASA is in charge of only orbital things and expects everybody else to do the ground-based stations the whole thing will not work. We are talking about very sophisticated ground-based observatories that are as sophisticated as an orbiter, and we need high-technology and we need a mandate, perhaps for NASA, to have zero elevation geosynchronous orbiters as well as the other kind of geosynchronous orbiters because the NSF's budget just cannot hack it.

Senator GORE. Who do you think ought to be in charge of it?

Dr. ANDERSON. Well, I am a scientist and not an administrator but I would think it would make sense, since NASA has the largest part of it and since they are the high techonology agency, that they be the lead agency, but the other groups like the USGS and the NSF and NOAA have to be involved. But at the moment their budgets are so disparate with that of NASA that NASA cannot say well, I will take this part and you guys take the rest of it, because the budgets are not there.

But NASA's mandate has to be either changed or people in NASA have to understand that this is a systems approach to science and not just say "I will do the orbiter and everybody else takes care of the rest of it."

Senator GORE. Dr. Ride, are you busy for the next 10 years?

Dr. RIDE. Yes, as a matter of fact.

I would like to echo what Dr. Anderson said. I think that there does need to be someone in charge of a program like this, because there are so many pieces. NASA has an important piece and is doing quite a bit towards advancing its piece, particularly the polar orbiting platforms, but it is just a piece. And you cannot I believe orchestrate such a major program without having someone in charge of the program.

I guess—I think that you could make NASA the leader of this program, but the problem that you have to first overcome is that

NASA traditionally believes that it is, above all else, exploring other worlds, exploring the space frontier, and that you would need to elevate this certainly in priority, I believe, in its perceived mission, before you could get effective leadership.

Senator GORE. Let me ask one question, Mr. Chairman. I thought early on when your report came out that NASA's reaction as an institution was less than enthusiastic. Perhaps that was because the institutional skeleton of NASA, the architecture, the structure of NASA, is really better suited to the kinds of things it has done in the past and, therefore, the various components of NASA looked at this idea and could not quite see big chunks for each center and how this new mission was matched to the kinds of structure that was there.

I have since been led to believe by many within NASA that the enthusiasm is developing and that they may look at it a little more favorably now. But what you just said tells me that maybe if we do encourage them to put somebody in charge of it, maybe it should not be NASA. That will be my last question on this.

Dr. RIDE. Let me just comment on that, because I think that while we were developing the report and while we were putting together the study and particularly putting together Mission to Planet Earth, we found a lot of support for it within NASA.

In fact, people within NASA were genuinely excited about the program, and I think what occurred was just a little bit of a conflict within everyone in NASA who said, this is a great program. The country needs to do it. You know, we have done remote sensing, we always put up earth observing satellites, but you know, is this exactly what our space charter is?

But the important thing to emphasize is, I think, that it did get a very good reception within NASA, and the people at NASA I think would be quite excited about leading it. I have not been at NASA in the last year and I have not been closely involved with the discussions that have gone on around it, so I am not really suited to say what the internal organization, how it would react to it.

Dr. FISK. Since we are talking about NASA here, let me at least make one comment. I think if you look at all of the four initiatives that were in fact put forth by the Ride report in terms of the planning to execute it this one is much further along, because the Earth Observing System, which is the key first step, and attached payloads and earth probes, three out of the four aspects of this thing will complete their planning cycle in June. We do not know how to go to Mars at the moment.

The CHAIRMAN. The whole question is, can you think of anyone better than NASA? I have the same concern as Senator Gore. We tried, Dr. Fisk, that approach of everyone answering up to their particular role, their responsibility, in the rescue of the hostages in Tehran, Iran, and they were still there. It was totally aborted. You have got to have somebody in charge. You have got the Army doing this, the Navy doing this, the Marines doing that, the Air Force doing this, but nobody is really in charge. When that occurs, you have got a disaster on your hands.

Dr. FISK. Let me comment a little further on this, because I do not want to be misunderstood about this issue. I mean, I have the

empire-building instincts of any good administrator, and the thought of taking charge has a certain appeal to me and so on.

The only real concern I have is a very practical one, which is there are a lot of things that NASA cannot do. We do not have the ground-based networks in place. The funding that the National Science Foundation gives, the USGS labs, all these things, these are existing programs which need to be taken advantage of, and so it is not as if NASA can create those entities. We should not do that. That is not efficient. We should make use of what already is in place.

So now you come to a very simple issue that if you say, all right, now you are in charge. Now there is no question that NASA should be in charge of the space part of this thing, and I would fight to my dying breath that that is exactly what in fact should occur. But when you say now you also want us to take over the leadership of the ground based, it requires the cooperation of the agencies which already have that in place.

Now how you get that is an interesting question. The President can come along and say, or the law can be passed or whatever that says, everybody salutes when NASA says, go do this. I would prefer to do this by persuasion, which says that the agencies which have these responsibilities, which have the infrastructure in place, are willing participants in this thing because they have a sense of their own identity in the activity.

That is the only issue, not that you need to make sure everything is done right, but there is a simple practical reality that one agency in this town does not tend to salute another agency.

The CHAIRMAN. Well, they will have to if we are going to really get the Mission to Planet Earth off the ground. Specifically, that is our problem in trade right this minute. We need, as badly as we urged for a drug czar, we need a trade czar.

We have got the Commerce Department, the International Trade Administration, the International Trade Commission, the Export Office, and all the trade policy you can imagine. Commerce thinks they are in charge until they run into Treasury Department and they say "no, we have got the tariffs, the reciprocal trade, the special trade representative." And then the State Department says "no you do not, it is a matter of policy over here", and then another Department comes in.

President Truman had this difficulty in foreign policy, who was in charge. He heard from Bill Casey of OSS and intelligence would indicate this. The State Department would then say no, the Defense Department would say no for security reasons. President Truman finally said, look, by Executive Order, I am going to put you down in the cellar underneath me. You fight it out and give me two or three options so that I can make a decision. But I cannot be refereeing fights every time you come up here with no options.

As a result, we got the Marshall Plan. The Executive Order put in the National Security Council and we got the Marshall Plan, the Atlantic Charter, the North Atlantic Treaty Organization, the Truman Doctrine; the far-sighted kind of foreign policy came from the little haberdasher of Independence, Missouri, because he knew how to make a decision.

That is the position and point that we have reached here in this committee, which goes right to the idea of trying to edge up to it to make the right decision.

Dr. Fisk, in your testimony you indicate that the Mission to Planet Earth is a part of the larger U.S. Global Change Research Program. Can you give us a better appreciation of the scope of the U.S. Global Change Research Program and how it relates to the Mission to Planet Earth?

Is it a part of the Global Change Research Program, or vice-versa? The Administration is going to file a report here shortly and we are trying to get a hold of this.

Dr. FISK. There is sort of a hierarchical system here, or at least the way I think of this thing with interrelated parts, that if you want to understand global change you need a global data set, global observations from space as has been said here, and Mission to Planet Earth is a concept for being able to do that. EOS, attached payloads, earth probes are the first step in that activity.

Now, when you actually say, now I have collected this data, let me go forth and use it to make assessments, to develop the models and so on, that is the U.S. Global Change Program. That is scientists out there in universities and national labs taking advantage of this data which is coming down from space, using the ground base data, doing the modeling and coming up with the research.

That is in turn then a contribution to the international geosphere/biosphere. There is a global change program in 40 countries out there we have the U.S., the Europeans have theirs, and so on, and they will be using this data which is coming down from the Mission to Planet Earth or the EOS first, and they will be using their ground based studies to do the models in an interactive way and produce a scientific consensus on the changes that are occurring to the environment and what the causes are.

The CHAIRMAN. Dr. Anderson?

Dr. ANDERSON. Could I give my response to that? This Mission to Planet Earth which I have been talking about is meant to be an all-encompassing, international, interdisciplinary issue that subsumes all of these other more specialized programs like climate change, global change, geosphere/biosphere, international lithosphere project, which has not been talked about and so on; it is the integrating of all of these.

So I would put it just the other way around, that global change is a small subset of Mission to Planet Earth. Geosphere/biosphere is just a small subset of it. Those things do not include the whole Earth. Mission to Planet Earth does, or should.

The CHAIRMAN. Well, with respect to the ground measurements you mentioned a little while ago, there is an uncertainty in assessing the ozone depletion problem, for example, due to the discrepancies between satellite measurements and ground-based measurements. Is this accurate, and how can we count on accurate measurements from the ground?

Dr. ANDERSON. We have got to have ground-based systems to complement the space-based systems. Some things you cannot do from space. For example, you cannot measure earthquakes. You cannot determine the locations of earthquakes, and some precur-

sory volcanic processes that happen in the ground you cannot determine from space.

The second aspect is, you have to have ground truth. You have to calibrate observations you get from orbit. Orbiters provide the global context, but you need ground-based calibration for almost everything you do from orbit, even though you cannot do everything from the ground.

It is an interlocking system; therefore, it does not make sense to say, one set of guys will do the space instrumentation and the space science, another group of guys with budgets that are only 1 percent or less of NASA's will be in charge of the lander-type instruments.

If we were going to go to Mars, there would be no question whatsoever that to do a complete integrated study of Mars, you would have to have some orbiters, and some landers and NASA would do it. When you come to the Earth, you also have to have landers, you have to have orbiters, but now you have the problem of the jurisdiction.

The CHAIRMAN. Dr. Ride, money and personnel. Obviously, we do not have the money for all of it at the moment. But for a good start, this can be done incrementally, I take it? Number 1, there is the space station and that is where we should start, at least. Let us say Senator Gore does not quite get it all in this year, or if we are going to get any part of it and get a good start and take advantage of the tide at its flood—a space station at least?

Dr. RIDE. Let me make a comment on the cost of the program, because you quoted a cost earlier of I think $20 to $30 billion over 10 to 15 years.

The CHAIRMAN. The CBO study said $22 to $24 billion over 10 years.

Dr. RIDE. I can, I think, shed some light on that. First of all, I think that the number $20 to $30 billion is actually supposed to be out to the year 2010, and the CBO study was based on the Mission to Planet Earth that was outlined in my report, and we had it done out to 2010. So the first comment is, extend the time frame that the CBO money covers.

The second comment is that, exactly as you said, you know, there are Missions to Planet Earth, and then there are Missions to Planet Earth. When we put together this initiative we were told from the very beginning to make it the Cadillac of initiatives.

Since it was being put forward as a U.S. leadership initiative and being compared to a Mission to Mars, a lunar-based planetary exploration, we essentially said, okay, for this study, money is no object. What is the best Mission to Planet—and it is probably only the NASA study that has ever been allowed to do that—what would be the best Mission to Planet Earth that we could put together going out to the year 2010 and in the year 2010 having this system in place and taking data?

So we did that. That is why we got the five geostationary satellites and we got them into orbit by the year 2000, which is extremely optimistic. Also, in the costing, when we laid out the elements of the Mission to Planet Earth, and when CBO did the costing, we attributed everything that would be required and we charged it to the program, including a heavy-lift launch vehicle

that might be required to get some of the things in orbit. We charged that to Mission to Planet Earth just because that was the only fair way to compare the initiatives. So you need to understand the background for the CBO's numbers, and I would encourage your staff to verify this with the CBO just to make sure.

But I think that my main point is that I do not believe that a Mission to Planet Earth need cost more than, call it as a rough number, a billion a year, and that is after you have ramped up over a few years. So I am very pleased that the committee might be willing to spend $20 to $30 billion over 10 to 15 years, but I do not think that that is necessary for the Mission to Planet Earth program that we have been talking about.

The CHAIRMAN. What would be the first order of business?

Dr. RIDE. I think the first order of business is sorting out who is in charge of the program and who has responsibilities for what pieces, and I cannot emphasize that enough, because that includes not only within the United States and the U.S. agencies but also on an international scope, and in regards to the international scope of the program I think this is an example of a program, and it may be one of the few good examples that we have got where there are genuine cost savings by making it an international program.

There is no question of having to duplicate platforms. If one group of nations puts up one polar platform, they can pay for that. If one nation decides to put a ground-based experiment in their country, they pay for that. So there is an honest cost savings in making it an international program.

The CHAIRMAN. How far along are we on that? I mean, we have been doing a lot of international conferring.

Dr. RIDE. I think I would defer to Len to answer that question.

Dr. FISK. Let me answer it a couple of ways. In the case of the Earth Observing System, the polar platforms, the attached payloads, it is completely coordinated internationally. There are planned to be two U.S. platforms, one European, one Japanese. The instruments are being selected now. There will be some U.S. instruments on the European, there will be some European on the U.S., and so on and so forth. So as far as the polar platforms and the attached payloads on the space station, the coordination is in place as an international program.

In the case of encouraging nations to participate through their ground-based activities, it comes in a variety of ways. The international geosphere/biosphere program is set up to do that; the ISY is set up to encourage that activity. That is evolving in time. But the polar platforms or space station activities which come to the planning conclusion this summer is set, as far as the international cooperation is concerned.

The CHAIRMAN. Along that line, Dr. Anderson, over at the National Science Foundation—you could help us. Dr. Block, Senator Gore and myself in November were down at the Antarctic. It seems to me a story of cooperation is already taking place on one of the seven continents, and it is ongoing.

It is all scientific. There is an interchange of visitation, interchange of scientific data. And we as politicians can go to our colleagues and say look, we are already doing it for one of the continents. And it is a sort of good example how it can work, and the

tremendous international interest and support that is there. I was impressed by it.

Dr. Ride, do we have the scientific talent now to correlate all this information?

Dr. RIDE. Yes, I think we do.

The CHAIRMAN. You are at Stanford, Dr Anderson at Cal Tech. We are constantly hearing that there is a tremendous shortage out there, and I was wondering what we could do if there is that shortage to, as you would suggest, provide for it. But you think we have got the scientific talent needed to make sense out of all this data?

Dr. RIDE. I misunderstood your question at the beginning and answered a little too hastily. I think that we have the scientific understanding to know exactly what we want to be observing, what data we want to be gathering, and we have got the understanding and the scientific talent to put the instruments in place to begin analyzing and gathering the data.

I think the other problem that you were talking about is encouraging the high school students of today to be entering these scientific fields in college and then pursuing their studies through graduate school, so that 10 years from now, or 15 years from now when we have got our Mission to Planet Earth in place, there will be the complement of scientists that are required to analyze the data.

I do not pretend to be an expert on this problem, except to know that it is a very real problem and that it is definitely worth the attention of the committee and of people around the country to try and solve the problem of encouraging young boys and girls in elementary school, even, is certainly not too young, but certainly junior high and high school to be pursuing careers in math and science.

Not only for, I think, the importance to our country of having a group of scientists to analyze the data, but also just of having, the importance to the country of having scientifically literate citizens, which is a major problem in the country right now.

The CHAIRMAN. Dr. Anderson?

Dr. ANDERSON. May I elaborate on that? Senator Hollings, you mentioned the NSF and I think you are right, the NSF is doing a lot with international coordination. There are many programs of the type you have mentioned. There is a Federation of Seismological Researchers that have networks that are integrated on a global basis and exchange data. There is an international lithospheric program that coordinates and exchanges data.

But I think the important thing is to recognize that the NSF will always be an important part of this Mission to Planet Earth. They are woefully underfunded in earth sciences and even before all this data starts coming in we can start increasing the amount of our research done on the earth with the present facilities that are set up. We can train more earth scientists in the next 10 years by adequately funding the earth science part of NSF. We should not wait to start this part.

The CHAIRMAN. Let me ask one question before I yield back to Senator Gore here. Yesterday I turned on the TV and they said if your signal is in any way disturbed there has been an explosion from the Sun. Well, back in November there was a fellow at the University of Rome doing research in Antarctica who says, come

listen over here, Senator, we have got bells in the Sun. I said, you have got bells? He said, listen to them, they are ringing; and you could see the flagellations on the chart, but I would be lying if I said I heard the bells.

But that was sort of like the birds flying away, anticipating an earthquake. There were some flagellations and disturbances there. Is that what happened now? And was that the signal for an impending explosion? Have we had the explosion from the Sun itself? Do any one of you three know? I am intrigued.

Dr. FISK. I suspect what you heard in the Antarctic was what are called micropulsations. They are essentially the ringing of the earth's magnetic field as a result of disturbances which come from the Sun. The large solar flare which occurred the other day is probably not correlated with that, except to say that we are going through a portion of the solar cycle at the moment.

We have gone through solar maximum, we are coming up to solar maximum activity, and as you go down the other side towards solar minimum the Sun tends to have large explosions on it—solar flares. So this is the time period in the 11-year solar cycle where very large solar flares tend to occur, and this was apparently a humdinger.

Dr. ANDERSON. But this also brings up a good point. In order to understand the earth's system you have got to study everything. You have got to study the Sun, and what is happening in the earth's atmosphere, and the magnetic field which is generated in the earth's core. You have got to go all the way down to the middle of the Earth to understand. This particular phenomenon, you have got to go all the way from the center of the Earth out to the Sun. You have got to study the whole system.

The CHAIRMAN. We went all the way down there to see the hole and the wind currents had sort of diminished. They were not as fast and caused a vortex in the space itself where you could see the hole. It is still that much diminution, let us say, of the ozone itself. They determined it scientifically but we just could not see it as clearly, as I remember, because of the winds.

Senator GORE. They explained that was due to what they called a QBO, or the quasi-biennial oscillation. I looked into that a little bit more carefully and was surprised to find that scientists really have no idea what causes this oscillation.

Every 13.5 months above the equator, the winds in the stratosphere reverse direction. Every 13.5 months, and 27 months for a full cycle. Why does it happen? We have absolutely no idea, and yet that is a critical factor in understanding the shaping of that ozone hole in Antarctica, and it is the kind of thing that Mission to Planet Earth would probably help us figure out fairly closely.

Also, you were talking about volcanoes. Some of the scientists at this meeting in London were saying that just as these very high, cold, polar stratospheric clouds above Antarctica provided surface area particles for that ozone-depleting activity to accelerate, volcanoes that presumably provide particulates at least for a two- to three-year period on which the same kind of reaction could take place in the mid-latitudes in the northern hemisphere, et cetera. Again, an important thing that the Mission to Planet Earth would help us to understand.

Should we have a separate line item in the budget for Mission to Planet Earth? A logical outgrowth of unitary management, if we solve that problem. Should we have a line item in the budget so that we could look and see as a committee exactly what is going on? Should that be the way we set up this program?

Dr. ANDERSON. Would the line item break out the contribution of the various agencies?

The CHAIRMAN. Whose line?

Dr. ANDERSON. If you had a line item, Mission to Planet Earth, a billion dollars here for the next 20 years subdivided in the following way: $100 million to NSF, $100 million to USGS, that kind of thing? Yes.

Senator GORE. I would like to not only see somebody in charge, I would like to see a presentation to the Space Subcommittee that tells us what it is costing from year to year in all its various components.

I would like to see a precise parts list, so to speak, for Mission to Planet Earth. Do you have any idea when we might be able to get an official cost estimate for all of the elements of Mission to Planet Earth by fiscal year through the end of the program?

Dr. FISK. Let me take a crack at that. A couple of things, I think, to note: you know, in the preparation of the 1990 budget, which you have before you, there was what is called a crosscutting exercise across the various agencies to show what was being spent on global change. You have that report.

It is one of these reports that you have to really understand the rules, though, because in the case of NASA, for example, which has an extensive activity in earth science besides the global change activities, that those costs are counted separately. That is, exclusively for, specifically, global change; and it is my understanding that in each and every year as the global change activities, Mission to Planet Earth, whatever name we can agree on that it would be called, is brought forth, that the budget process will show in each and every agency what is being spent on that.

Now as for the total cost in the run out, I suspect that NASA of course will drive this system because it is the space components which are always the most expensive to be able to execute. The economy is such that it is a lot cheaper to get that data from space than to try and get it from the ground because you cannot have that many stations all around the world, but nonetheless the cost associated with the space component will be the largest single cost.

Our planning exercise will produce very definitive costs for EOS and earth probes, and so this summer that is the activity that we would bring to planning for a budget decision at that time. Geostationary platforms is just simply beyond our understanding of the technical issues at the moment, so it would be very hard to give a cost associated with them.

Senator GORE. Well gosh, I mean, just to take one example—data management. This is in the charge you have given us. Data management——

The CHAIRMAN. Excuse me, Senator. If we can include this chart in the record at this point, we want to put it in that record.

[The chart referred to follows:]

Our Changing Planet:

A U. S. Strategy for Global Change Research

A Report by the Committee on Earth Sciences

To Accompany the
U. S. President's Fiscal Year 1990 Budget

Table 1
1989-1990 U. S. Global Change Research Program Budget
(Dollars in Millions)

Focused Program	Total Budget		Biogeochemical Dynamics		Ecological Systems and Dynamics		Climate and Hydrologic System		Human Interactions		Earth System History		Solid Earth Processes		Solar Influences	
	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990	1989	1990
Agency Totals	133.9	190.5	29.8	44.9	28.1	39.5	38.0	59.3	22.0	22.0	3.0	7.0	8.9	10.5	4.1	7.3
NSF	39.2	53.5	13.5	18.3	1.9	1.9	13.2	17.0	0.0	0.0	2.0	4.7	6.2	6.5	2.4	5.1
DOE	20.2	27.2	6.0	5.5	4.2	6.7	7.0	10.2	2.0	3.6	0.0	0.0	0.0	0.0	1.0	1.2
DOI/USGS	5.3	10.3	0.0	0.0	0.0	0.3	2.3	5.0	1.5	2.0	1.0	2.3	0.5	0.7	0.0	0.0
NASA	14.5	21.5	3.0	4.4	4.3	6.4	4.3	6.4	0.0	0.0	0.0	0.0	2.2	3.3	0.7	1.0
DOC/NOAA	9.0	20.0	0.0	3.0	0.0	0.0	9.0	17.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EPA	27.4	35.3	0.8	3.5	7.4	13.2	0.7	2.2	18.5	16.4	0.0	0.0	0.0	0.0	0.0	0.0
USDA	18.3	22.7	6.5	10.2	10.3	11.0	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Activity	133.9	190.5	29.8	44.9	28.1	39.5	38.0	59.3	22.0	22.0	3.0	7.0	8.9	10.5	4.1	7.3
Research	116.4	158.9	26.9	40.1	24.9	35.0	31.6	46.1	22.0	20.8	3.0	3.5	5.4	8.1	2.6	5.3
Observations	10.7	15.0	0.0	1.5	2.0	2.5	5.0	8.5	0.0	0.0	0.0	0.0	3.5	2.2	0.2	0.3
Data Management	2.3	8.1	0.4	0.8	0.2	1.0	1.4	4.7	0.0	1.2	0.0	0.0	0.0	0.2	0.3	0.2
Facilities	4.5	8.5	2.5	2.5	1.0	1.0	0.0	0.0	0.0	0.0	0.0	3.5	0.0	0.0	1.0	1.5

Senator GORE. I think that is appropriate. Table 1 on pages 24 and 25 of the report by the Committee on Earth Sciences. Data management for human interactions with global change zero. In 1989, $1.2 million; in 1990, the total data management, $8 million by 1990. You are not just going to double the amount of data you are dealing with. You are not going to quadruple it. You are not going to increase it by an order of magnitude, or 10 times, you are going to increase it by 200 orders of magnitude, 2,000 as much data. You are going to do that for $8 million?

Dr. FISK. Senator, I think what you point out there is going to be one of the challenges in the accounting system of how we deal with this. NASA has an earth science program which we currently spend between $400 and $500 million a year on. That is the basic earth science program. It includes all the research and analysis to universities. In addition to that——

Senator GORE. But that is the one that is going to be multiplied by 2,000.

Dr. FISK. I am aware of that, but if I might just finish my point. There are 22,000 NASA employees which are counted in that bookkeeping, because that is kind of a small sum above and beyond this relatively large base, and I think that one of the challenges that is going to occur throughout this system, when you say, you know, what can the agencies bring to the table in order to successfully do the Mission to Planet Earth, there exists in every agency this large basic structure which is currently being spent on very similar and related, in some cases direct activity associated with it. That contribution understates the contribution by as many orders of magnitude as we will have data.

Senator GORE. If it is okay with the chairman I would like to request a follow-up written presentation from NASA on what the estimates, year by year, are for the Mission to Earth program. I am a

little confused about the overlap between Mission to Earth and the total global change. Who is in charge of one and who is in charge of the other? What the cost is, et cetera. Specifically, if you could give a little more detail on what your plan is for the data management task.

Now because time is running out here, let me just ask a couple more brief questions with the chairman's indulgence. In the area of international cooperation, you said that you have got that underway on the polar platforms and the attached payloads. What about the geostationary platforms?

Dr. FISK. It is a very preliminary study at the moment. Some discussions, but it is an early phase A study in which we have had some meetings on it. But we are probably, if you asked in terms of years, we are four to five years ahead in doing the polar platforms than we are in doing the geostationary.

Senator GORE. Are the Russians going to play a role?

Dr. FISK. The way we deal with Russians on this issue is through the bilateral agreement which was signed in April of 1987.

We have had discussions with them about the possibility of their participating in this program and on their contributing instruments, even platforms to it. They are at a very early stage. They will be here next week.

Senator GORE. You are aware Gorbachev specifically singled this out in his speech to the United Nations in January?

Dr. FISK. I am indeed, and this is the first meeting that we have had with them as part of our bilateral since that speech.

Senator GORE. Dr. Ride, how can the developing nations participate in this program?

Dr. RIDE. I think the developing nations can play a major role because of the ground-based requirements for the program. Although the developing nations would probably not want to contribute space-based experiments just because those are generally higher technology and also more costly, they certainly can and would certainly benefit from providing experiments that would measure a whole range of interesting parameters in their own country. And I think that not only could they contribute data to the overall Mission to Planet Earth, but they could probably also benefit quite a bit themselves just from the data that they could collect.

Senator GORE. In conclusion, Mr. Chairman, I want to express again my strong support for this and note that this mission will not only give us the ability to understand these long-term trends, it will give us the ability to measure the effects of policies being put in place in the short-term.

For example, if we have a 50 percent reduction in the chlorofluorocarbon levels produced each year within the next two or three years, the only way we could quickly understand what effect that is having is with this kind of system. So we will not have to wait 20 years to adjust those policies and verify how they are working.

I mean, we are at a stage in the 1990s where we will be facing a decade of decision on the earth's environment. I do not want to sound shrill on that, but I really believe that is the case.

One final note. Again, I do not want to harp on data management, but the National Academy report indicated that "the present ability and time required to translate space observations into analysis and understanding, the field of data interpretation, lags well behind the technology to build measurement devices and to collect data from space.'

I just want to close by underscoring my concern that we have got to have the organizational structure thought through, and we have got to have a much clearer presentation of how we are going to confront and solve this most difficult part of the challenge. Mr. Chairman, I appreciate the chance to join with you in this.

The CHAIRMAN. Well, I thank you. The interest that we have had here this morning from all the members reflects their interest. We have got conflicting assignments but we had a good turnout this morning. The Committee is indebted to each of you this morning, and I know you have traveled far to make this contribution, and to me it has been a very significant contribution. We thank you, and the Committee will be in recess.

[Whereupon, at 11:39 a.m., the hearing was adjourned.]

[The following information was subsequently received for the record:]

It is important to remember in any discussion of Mission to Planet Earth that it is a preliminary concept study of a possible future mission, not an approved program. Mission to Planet Earth is a NASA umbrella term for the space observation platforms, data and information system, Earth process studies, and global Earth system models which, combined, move toward the goal of understanding global change. Mission to Planet Earth is NASA's contribution to the larger U.S. Global Change Research Program that was outlined in the report by the Committee on Earth Sciences (CES) that accompanied the President's FY 1990 budget. The CES is in charge of the implementation of the U.S. Global Change Program; the CES works in concert with the National Academy of Sciences Committee on Global Change, which is in charge of coordinating and directing the science effort of research.

The study of global change has been a priority within the Earth Science and Applications Division of the Office of Space Science and Applications for a number of years. The Stratospheric Aerosol and Gas Experiment, launched in 1979 and still functioning, the Earth Radiation Budget Satellite, launched in 1984 to measure solar energy output to Earth, and the Total Ozone Mapping Spectrometer launched on Nimbus-7, are just three examples of missions designed to study global change. The current Earth Science and Applications program is a precursor effort supporting a Mission to Planet Earth concept. In addition, several other U.S. agencies are supporting the U.S. Global Change Program effort.

Data management has been a key concern in the development of this concept from the beginning. The current vision of a Mission to Planet Earth concept places significant emphasis on a ground based data management element, whose key component would be a data and information system which gathers, processes, and archives the data arriving from various space elements. The information archived in the data and information system would be accessible by the entire world-wide scientific community. The information would consist of global maps of surface temperature, precipitation, soil moisture, cloudiness, radiation budget, and other global data sets.

A current configuration concept for a Mission to Planet Earth type program includes Earth Probes, Eos/Polar Platforms, Eos/Attached Payloads, and Geostationary Platforms. However, it is important to note that these elements have not been fully defined, and will continue to evolve as the needs of the effort become more fully understood. As key reviews for the various elements have not yet been held, all cost estimates are tentative and likely to change based on Agency and administration budget decisions.

Earth Probes

Earth Probes is not an approved program. Therefore, studies for this project are in the early definition phase. The program would be managed similarly to the Physics and Astronomy Explorer program, in which spacecraft development is phased according to funding availability within a level-of-effort budget. The Earth Probes

Program is estimated to build to a $40-$60 million per year (constant dollars) level-of-effort program.

Eos/Polar Platforms

Eos is not an approved program. Preliminary planning indicates a first year budget requirement for the Eos program of $100-$125 million; this estimate includes the cost of instruments, integration, and related data and information systems for the first platform (NASA Polar Orbiting Platform or NPOP-1). This platform is being provided by the Space Station Freedom program.

Eos/Attached Payloads

The Eos program is planned to include Space Station attached payloads. The selection of these payloads has not yet been completed; however, a candidate list includes:

Earth Radiation Budget Instrument
Moderate Resolution Imaging Spectrometer
Rain Radar
Multifrequency Imaging Microvave Radiometer
Precise Position System - Precise Orbit Determination System
Scatterometer
Ozone Sensor
Special Imager

Since the selection is not complete and the full complement is not yet known, a total funding estimate is not yet possible.

Geostationary Platform

As mentioned above, the Geostationary Platform is not an approved program. In fact, this program, currently being studied for launch in 2005, is in the very beginning stages of definition studies. Therefore, no cost estimates are known at this time. Since we are still in the early stages of definition studies, there is a potential for international cooperation in this element of the program.